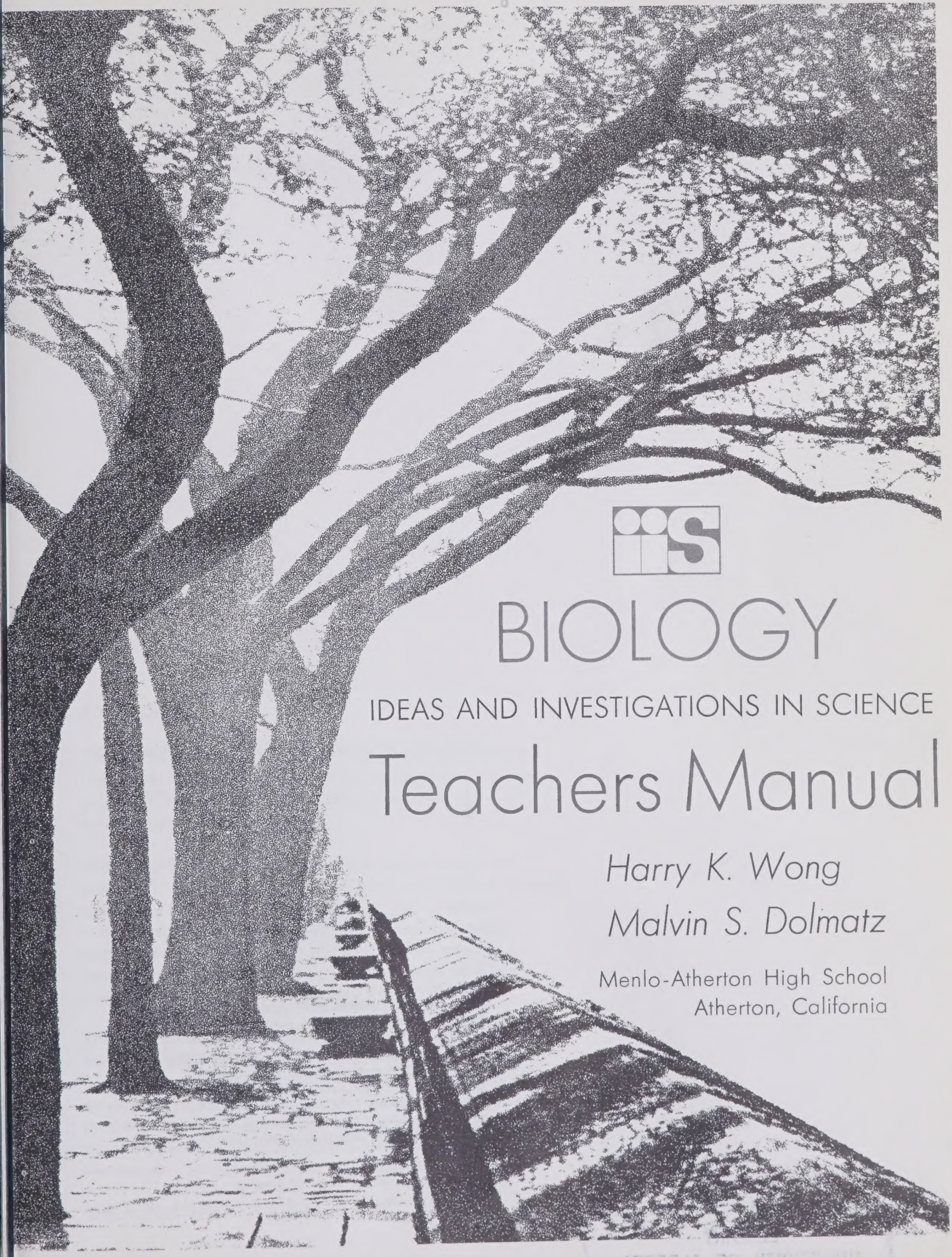
Wong and Dalmatz

BIOLOGY

Teachers Manual

IDEAS AND INVESTIGATIONS IN SCIENCE



BIOLOGY

IDEAS AND INVESTIGATIONS IN SCIENCE

Teachers Manual

Harry K. Wong
Malvin S. Dolmatz

Menlo-Atherton High School
Atherton, California

Prentice-Hall, Inc., Englewood Cliffs, New Jersey

Dedicated to the students of Menlo-Atherton High School

TEACHERS MANUAL
Ideas and Investigations in Science–BIOLOGY
Harry K. Wong *and* Malvin S. Dolmatz

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FOREWORD

The slow-to-average student whose formal education ends with high school poses unique problems for educators and publishers. These students have special needs that most current programs do not satisfy.

With this problem in mind, we have published a new science program, IDEAS AND INVESTIGATIONS IN SCIENCE, designed specifically for the non-academic student. This program is structured to encourage involvement by allowing every student to earn a passing grade and by providing actual laboratory experience where he can see first-hand what he must learn.

This Teachers Manual explains some of the major features of the program and how they can be best implemented. It will provide you and your students with valuable assistance in achieving a rewarding year of learning. After you use this program for the first year, we believe that you will concur with our enthusiasm for the opportunities it offers. To that end we wish you, good teaching, and your students, good learning.

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PREFACE

. . . deprived
. . . disadvantaged
. . . alienated
. . . isolated

It makes no difference what you call them, we do have many students in our schools who are EDUCATIONALLY UNINVOLVED.

IDEAS AND INVESTIGATIONS IN SCIENCE recognizes the needs of this segment of the school population. These students are not inferior; they are merely different and they require and deserve materials tailored to their unique characteristics and needs.

IIS is a program that stresses those few major concepts of science that every person should know if he is to be scientifically literate. It also emphasizes the ways or processes by which scientists form ideas, make discoveries, and contribute to the advancement of society. IIS involves the student in daily activities in which he discovers truths for himself. It is designed to prepare him for living in a world that is greatly influenced by science.

Science is not an encyclopedic collection of facts, nor is it a neatly separable set of processes. Rather, it is an ever-changing activity of man, involving the active construction of models and theories based upon systematic observation. Observation and the construction of models and theories are essential ingredients of IIS.

Major ideas of science are developed through a series of related investigations, each allowing the student to discover one concept at a time. The investigations are brief, requiring from one to three class periods to complete. The program has an easy reading level; paragraphs and sentences are short and, where necessary, are broken by illustrations so that no intimidating blocks of prose appear.

Most of the student's class time is spent in the laboratory where he learns from real experience. The time not spent in the laboratory is spent discussing and summing up class data. The necessary equipment for IIS is inexpensive and readily available.

The IIS materials are relevant to the student's own world, while exposing him to ideas which will lure him toward wider horizons. Science is studied in its social context: Problems such as pollution, population explosion, smoking, venereal disease, nuclear testing, and space exploration are part of the investigations. The investigations speak directly and meaningfully to the student, using *his* language and vocabulary.

Through careful structuring and the use of various processes of science, IIS leads students to discover inductively the major concepts and ideas of science, and develops in them a perspective from which to appraise and judge future events in their lives in which science is a factor.

Harry K. Wong

Malvin S. Dolmatz

To the Prentice-Hall editorial, production, and art staffs we extend our thanks for their many contributions of both imagination and hard work, and to Miss Susan Archer, our secretary, our gratitude for uncomplainingly typing the many drafts of the manuscripts and keeping two difficult authors organized.

H.K.W.

M.S.D.

CONTENTS

iis

HOW TO GET MAXIMUM RESULTS FROM IIS AND FROM THE TEACHERS MANUAL

You're a teacher and this book is written for you—to give you all the help possible so that both you and the student may be successful with IIS.

1. Know your audience. IIS is for the disinterested student who requires a special approach. See "What Is the Teacher's Role in IIS?" (page 1).

2. Know how IIS is organized. See "What Is the Content of IIS?" (page 3).

3. Explain the course to the students. Tell them that they will be learning a set of concepts as they work through a series of investigations. See "How Is Inquiry Used to Teach Content in IIS?" (page 14).

4. Make science socially relevant by using the opportunities provided in many of the investigations. See "How Is IIS Socially Relevant?" (page 16).

5. Read "How to Teach the Program" (page 18) and "How to Prepare Each Laboratory Investigation" (page 20), and note how the guide for each investigation is organized (page 20).

6. Use assistants or aides to help you set up each investigation.

7. Order all your supplies early. A master supply list for Biology is on page 225.

PHILOSOPHY OF IIS

What Are the Objectives of IIS?

Each year over two million high school students enroll in some kind of general science course. This enrollment is greater than that in any of the college preparatory science courses such as biology (only 1.85 million), chemistry, and physics.

These students are the largest segment of our high school population—the non-college-bound, average, science-shy students. They are future housewives, salesladies, secretaries, mechanics, bus drivers, and laborers. They are of average and perhaps below-average intelligence, and some day they will form the heart and backbone of American society. Yet these students have been neglected in most of our curriculum reform programs.

The challenge of these students motivated the authors to initiate a project in 1964, the purpose of which was to develop a science program for the student who may

a. come from an economically disadvantaged environment, which has caused him to fall behind in school.

b. be uninterested in traditional school activities.

c. come from a minority cultural background.

d. find it difficult to learn from traditional methods, such as lectures and books.

The materials developed by the authors were tested and revised annually for four years before they were tested nationally by a panel of 29 pilot teachers in nine urban centers under the sponsorship of Prentice-Hall, Inc. The resulting program, called *Ideas and Investigations in Science* (IIS), has the following objectives:

1. To use the major conceptual themes as the content framework.

2. To derive a sequence of concepts from a series of laboratory investigations.

3. To involve the student in the processes of science as he uncovers each concept in the laboratory.

4. To make possible continued success for the student.

5. To make scientific problems with social implications an integral and relevant part of as many lessons as possible.

6. To use examples familiar to the urban and non-white student.

What Is the Teacher's Role in IIS?

Educators have long recognized that any successful program must be student-centered. IIS has been designed with the student at the center of the program. Students spend most of each IIS day working on an investigation, either personally or with a partner, or involved in a class discussion.

The teacher's role in such a program is unique and requires a special orientation.

1. An IIS teacher should be one of the more experienced teachers who has an understanding of the new generation of science programs; for example, BSCS, CHEMS, and IPS. The IIS program is strongly process-oriented and should be taught by a teacher who recognizes the value of teaching process and content simultaneously.

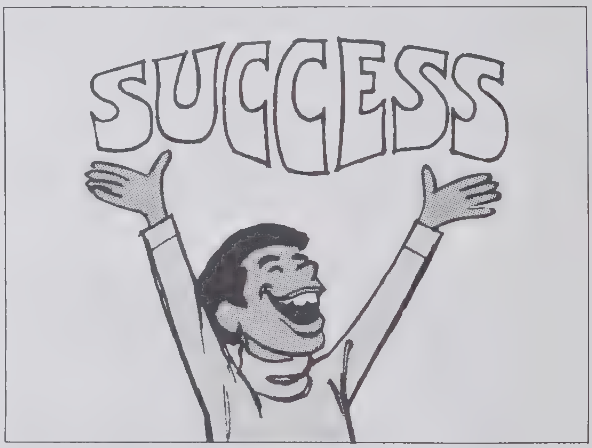
2. An IIS teacher should have enough confidence in his teaching ability to refrain from lecturing. Students must be allowed to become the active agents in the educational process.

3. An IIS teacher should become involved with the students. The IIS program is centered around teacher-guided inquiry, not unassisted discovery.

4. An IIS teacher should react to the students' need for approval and affection. A constant smile, a warm but firm hand, and a genuine concern will usually break down any facade of belligerence thrown up by the student.

5. An IIS teacher must never exhibit cynicism. Many uninvolved students have a strong feeling of fatalism, helplessness, dependence, and inferiority in social and academic situations. The IIS teacher should frequently praise his students.

6. An IIS teacher should assist the students to achieve success. There is *nothing* to be gained by failing students. Success can be enhanced by reading the investigations together as a class, discussing class data, and coming to a conclusion based on class agreement.

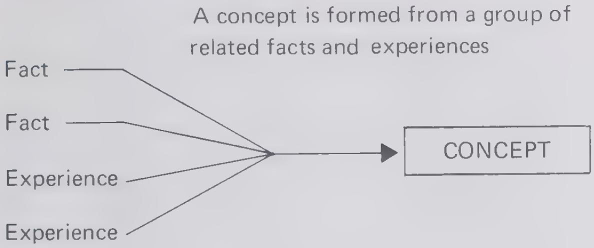


7. An IIS teacher should be given the best laboratory, schedule, and equipment possible. The uninvolved student should not be given substandard laboratories and inadequate equipment.

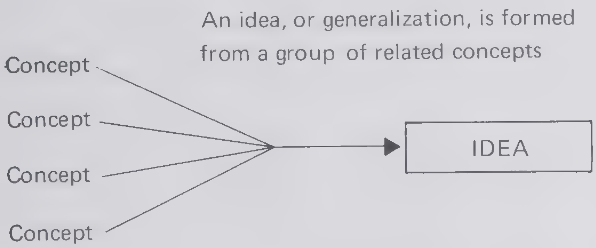
8. An IIS teacher should teach science with a focus on values. He should give meaning to science and its influence on the material, social, and intellectual life of our time.

What Is the Content of IIS?

The IIS program develops concepts and ideas in a vertical manner. There are 108 investigations, organized into ten major Ideas. Each investigation consists of a set of related facts and experiences from which the student derives a concept.



A series of 9 to 12 related concepts builds up to each Idea, which can be pictured as a sequence of related concepts developed in a vertical manner.



The horizontal structure of the IIS program is based on the Ideas, which represent one view of the conceptual framework of science. There are five Ideas in the biological sciences and five in the physical sciences.

Biology Idea 1, *Inquiry:* Science is an activity, a way in which man discovers more about his natural world.

Biology Idea 2, *Evolution:* The great diversity of life has come about because living things have been changing through time.

Biology Idea 3, *Genetics:* All living things have passed on traits from generation to generation with a continuity of pattern.

Biology Idea 4, *Homeostasis:* Life is a continuous struggle to keep various processes at a suitable balance.

Biology Idea 5, *Ecology:* All living things constantly need energy as they interact with their environment.

Physical Science Idea 1, *Predicting:* Science is an attitude, a method, an activity of man interested in finding out more about his natural environment.

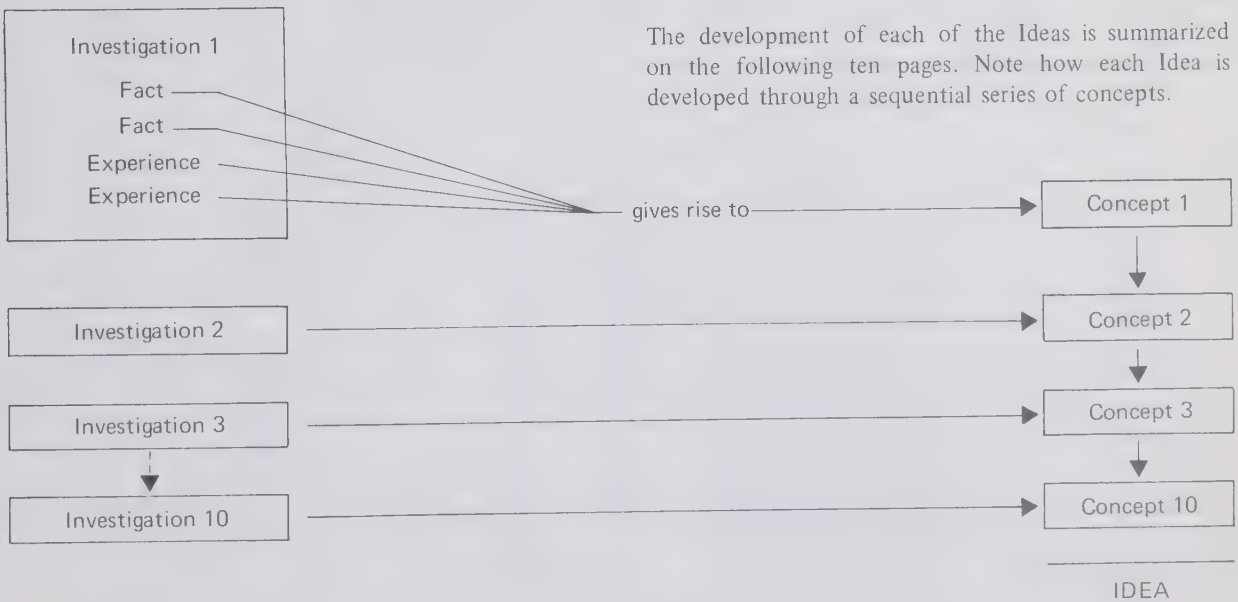
Physical Science Idea 2, *Matter:* The universe is composed of matter and all matter is made of tiny particles.

Physical Science Idea 3, *Energy:* When particles of matter interact, energy may be either released or absorbed.

Physical Science Idea 4, *Interaction:* Matter and energy are constantly interacting, producing our changing environment.

Physical Science Idea 5, *Technology:* Man's understanding of the interactions of matter and energy allows him to control his environment.

The development of each of the Ideas is summarized on the following ten pages. Note how each Idea is developed through a sequential series of concepts.



BIOLOGY: IDEA ONE (INQUIRY)

Science Is an Activity, a Way in Which Man Discovers More About His Natural World

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. WHATEVER TURNS YOU ON	A problem is recognized when a person senses something that does not agree with his mental ideas.	Discrepant events: lemon and soda in tea; card blowing; chair lifting
2. MAN, WE NEED CHANGES	The recognition of problems depends on accurate observations.	Chewing crackers; mealworm observations; 9 square game
3. DON'T BE AFRAID TO GUESS	A scientist makes predictions to guide the solutions to a problem.	Germinating seeds wrapped in different plastics; guessing objects in sealed box
4. PETALUMA IS A SWINGING TOWN	Controlled experiments are run to test the predictions.	Analyzing breath for carbon dioxide; constructing controlled experiment
5. WEIRD HAROLD WEIGHS 45,500	Accuracy is improved when common units and numbers are used.	Creating units and determining length, weight, and volume
6. LET'S GET ORGANIZED	Results of experiments should be organized into data tables.	Measuring pupil size against light intensity
7. CAN YOU SEE AS WELL AS JOSÉ?	Graphs should be used to aid in the organization and interpretation of data.	Designing histograms, bar graphs, and line graphs
8. DO YOUR OWN THING	Conclusions must be based on the evidence collected.	Interpreting tables, graphs, and experimental data; observing weight changes in soaked seeds
9. IF IT'S HAPPENING, BABY, IT'S HAPPENING TO YOU	Science is an activity, a thinking process, used by man to solve problems about his natural world.	Two inquiry problems

BIOLOGY: IDEA TWO (EVOLUTION)

The Great Diversity of Life Has Come About Because Living Things Have Been Changing Through Time

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. YOU CAN'T HELP BUT BUMP INTO ONE	There are many different kinds of living things (diversity).	Photographs showing diversity
2. DON'T CALL IT DIRT	There are many different kinds of life in soil.	Isolation of organisms from soil
3. HUMAN SENSES ARE SO POOR	Microscopes extend the senses to help us see the great diversity of life.	Use of the microscope
4. WHAT'S SO COMPLICATED ABOUT WATER?	There is a great diversity of life in a drop of water.	Observation of organisms in water
5. ALL MEN ARE CREATED EQUAL	Despite the diversity of life, all living things are made of cells.	Observation of various cells
6. IS THERE ORDER TO CHAOS?	Living things can be arranged into related groups (classification).	Grouping cards and cutouts
7. PUNCH CARD A YELLOW-BELLIED SAP-SUCKER?	Order in classification is based on body structure.	Sorting data punch cards
8. YOU CAN'T SEE THE FOREST FOR THE ROCKS	Fossils furnish evidence for living things in prehistoric days.	Making fossil replicas
9. A HORSE, IS A HORSE, IS A HORSE?	Fossils furnish evidence that living things have changed through time.	Graphing growth of horse
10. VARIETY IS THE SPICE OF LIFE	There is variation within each species.	Graphing pea size, leaf length, reaction distance
11. SURVIVAL OF THE FATTEST	Nature selects the fittest to survive.	Selecting out colored cutouts
12. PEOPLE ARE BEAUTIFUL	Skin coloration is the result of natural selection.	Reading on origin of skin coloration

BIOLOGY: IDEA THREE (GENETICS)

All Living Things Have Passed on Traits from Generation to Generation with a Continuity of Pattern

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. AND THE BEAT GOES ON	Life comes from previous life.	Pasteur swan-neck experiment
2. DON'T CROWD ME, BABY	A population can multiply very rapidly.	Bacterial growth; population control
3. LOOK MA, NO PA	Some organisms reproduce by dividing, a method requiring only one parent (asexual).	Observation of ameba, paramecium, yeast, hydra, and onion root tip cells
4. DON'T PEAS COME IN CANS?	In sexual reproduction, two cells are involved and the offspring do not look like the parents.	Flower dissection; pollen tube formation
4A. THE EPIDEMIC NO ONE TALKS ABOUT	Venereal disease is a serious problem of epidemic proportions.	Reading about venereal diseases
5. THAT'S USING THE OLD BEAN	A pattern of inheritance can be observed over a period of generations.	Analyzing a series of bean crops
6. LET'S HAVE A PEA PICKIN' TIME	The pattern of inheritance can be predicted.	Analyzing a series of pea crops
7. WILL YOUR PREDICTION GO UP IN SMOKE?	The environment can affect the appearance of an inherited feature.	Examining genetic tobacco seedlings
8. WHAT'S A CLEAR CHIP WORTH?	Each offspring receives one "bit of information" for each feature from each parent.	Selecting plastic chips which represent features; model building
9. IT'S A DOG'S LIFE	One "bit of information" can dominate and hide another "bit of information."	Review of Investigations 5 to 8; plastic chips
10. IT TAKES BRAINS TO GAMBLE	You can determine the odds on the features an offspring will inherit.	Calculating odds
11. WRINKLED PEAS FOR DINNER?	A "bit of information" can direct the activities of a cell.	Conversion of sugar to starch with pea seed enzyme
12. I AM THE SECRET OF LIFE	The hereditary "bits of information" are carried on the chromosomes (as a chemical substance called DNA).	Observing chromosomes; karyotyping

BIOLOGY: IDEA FOUR (HOMEOSTASIS)

Life Is a Continuous Struggle to Keep Various Processes at a Suitable Balance

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. ARE YOU GROOVY AND IN GEAR?	Living things must respond to a stimulus.	Response experiments with seeds, pulse rate, and snails
2. LET'S COOL IT	Different stimuli can cause different responses.	Heartbeat rate of Daphnia; capillary flow in a goldfish
3. NO SWEAT	Each response is made to keep the organism at a constant state.	Measuring sweat gland activity and body temperature
4. WE MUST WORK TOGETHER	Different body functions must work together to keep the body at a constant state.	Measuring pulse, breathing, and gas production rate
5. THE BIGGEST PUT-ON IN LIFE	Overstress can upset a constant state.	Smoking and breathing
6. KEEP YOUR COOL AND KEEP IT STEADY	Each body function operates best at its particular constant state.	Digestion of starch with enzymes
7. A REAL MOVING STORY	Membranes help the body to regulate its constant state.	Diffusion and osmosis
8. HOW'S YOUR BLOOD SUGAR?	Hormones help the body regulate its constant state.	Effect of hormones on seeds and chicks
9. WHAT'S THIS SCENE ALL ABOUT?	The nervous system coordinates the life functions necessary to maintain a constant state.	Drug abuse
10. THE GAME OF HOMEOSTASIS	Life is a continuous struggle to keep various processes at a constant state.	Academic game with cards

BIOLOGY: IDEA FIVE (ECOLOGY)

All Living Things Constantly Need Energy as They Interact with Their Environment

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. YOU EAT NEARLY A TON OF FOOD	All living things constantly need energy.	Burning nuts; measuring calories
2. A STORY THAT'S FULL OF HOLES	Plants need carbon dioxide and light to make starch.	Finding stomates; testing leaves for starch
3. THE IMPORTANCE OF BEING GREEN	Plants need chlorophyll to maintain life.	Chromatography of chlorophyll
4. YOUR LIFE DEPENDS ON PLANTS	Plants produce oxygen.	Measuring oxygen production
5. BUBBLE, BUBBLE, TOIL—NO TROUBLE	Carbon dioxide is released when food is broken down for energy.	Respiration of yeast
6. LOOK, THERE IN THE FOOD!	Living things need oxygen to release energy if life is to continue.	Respiration of pea seeds
7. A CITY FULL OF NATURE	A community is an organized group of populations living in mutual dependence (and is dependent upon energy for survival).	Ecological survey
8. A MOLD CAN SAVE YOUR LIFE	All living things compete with other living things for the available energy in a food web.	Bacterial competition
9. IT'S A SMALL WORLD	A succession of organisms can be observed in a community until a climax is established.	Succession of microorganisms
10. BEAUTIFUL DOWNTOWN BURBANK	Destructive influences can upset a climax community.	Measurement of oxygen; pollution

PHYSICAL SCIENCE: IDEA ONE (PREDICTING)

Science Is an Attitude, a Method, an Activity of Man Interested in Finding Out More About His Natural Environment

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. DO YOU SEE WHAT I SEE?	The recognition of problems depends on accurate observations.	Describing hidden objects; interpreting photographs
2. IT'S A REGULAR HAPPENING	Natural events tend to repeat themselves.	Swing pendulums; Cartesian divers; shake bottles
3. WHAT DO YOU PREDICT?	A prediction (hypothesis) is made to direct the possible solution of a problem.	Different kinds of balls dropped
4. PUT UP OR SHUT UP	The purpose of an experiment is to supply evidence to support or reject the prediction.	Weights bounced on hanging springs
5. BIGGER THAN WHAT?	Experiments must have controls.	Pendulums with different weights
6. STANDARD SIZE	There must be standards of measurement.	Making toy fences with nonuniform bolts and nuts
7. OH, IT'S DOWN YONDER	Accuracy is improved when measurements are recorded as numbers.	Filling 1 cc and 1000 cc plastic cubes with water
8. WILL YOU BE A DROPOUT?	Tables simplify the recording of data.	Measuring heights of balls' bounces; pendulums of different lengths; making data tables
9. 40,000 JOBS LOST PER WEEK	Graphs simplify the interpreting of data.	Making and interpreting graphs
10. DON'T STOP ME, MAN–I'M REALLY MOVING	Conclusions must be based on the evidence (data) collected.	Timing the roll of balls
11. SCIENCE IS WHERE THE ACTION IS!	Summary of concepts from first 10 investigations.	Using scientific method to solve a game-type problem; 2 persons joined at wrists by string

PHYSICAL SCIENCE: IDEA TWO (MATTER)

The Universe Is Composed of Matter and All Matter Is Made of Tiny Particles

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. THAT'S ABOUT THE SIZE OF IT	All matter has the properties of weight and volume.	Weighing and measuring various objects
2. JUST HOW MUCH IS IN THAT BAG?	Density is the ratio of weight and volume.	Computing density from weight and volume
3. TIME FOR A THAW	The total amount of matter present remains the same whether it takes the form of a solid, liquid, or gas.	Weighing ice and water
4. A ROSE BY ANY OTHER NAME	The amount of matter remains constant during a change of state.	Weighing and melting sulfur
5. SOMEHOW IT'S NOT THE SAME	The total amount of matter present remains the same during a chemical change.	Weighing substances before and after a chemical change
6. ONE AND ONE DON'T MAKE TWO?	Matter acts as though it is made of particles.	Measuring volume of solutions and mixtures
7. IT'S A GAS	Matter reacts in constant proportions.	Measuring products of reaction of magnesium and hydrochloric acid
8. LET'S BREAK SOMETHING	Matter breaks up in constant proportions.	Electrolysis of water
9. DON'T GO TO PIECES	Matter is composed of different elements, each consisting of atoms.	Heating mercuric oxide; decomposing sodium peroxide in sulfuric acid
10. WHAT GOES ON IN THERE?	Atoms contain smaller particles.	Static electricity; electroscope; Geiger counter; graphing radioactive decay
11. MAKE YOUR OWN PIECES	Atoms are made up of protons, neutrons, and electrons.	Knocking marbles out of a circle

PHYSICAL SCIENCE: IDEA THREE (ENERGY)

When Particles of Matter Interact, Energy May Be Either Released or Absorbed

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. I COULD WATCH IT BY THE HOUR	Work is force acting over a distance.	Rolling a spool with a rubber band; getting heat from bending a paper clip
2. IT'S ALWAYS WORK	Work takes many forms, such as light, heat, and electricity.	Radiometer; electromagnet
3. THERE MUST BE AN EASIER WAY	Work is made easier with simple machines.	Measurements based on pulley; lever
4. IS THIS ON THE LEVEL?	Simple machines make work easier by using less force over a longer distance.	Measurements on an inclined plane
5. HEAT MAKES WORK AND WORK MAKES HEAT AND–	Burning fuel does work through the expansion of heated gases.	Motion of test tubes and pin wheels produced by expanding gases
6. STOP FUELIN' AROUND	Fuels release energy by reacting with other matter.	Paper burned in closed container; temperature changes from dissolving chemicals
7. GO MAD WITH POWER	Energy comes from reacting nuclei of atoms.	Exposure of film by radiation and heat; solar cell; a simulated chain reaction with wooden blocks
8. DON'T LET IT RUB OFF ON YOU	Radiation safety depends on shielding, space, and money.	Geiger counter readings with changes in distance and in shielding
9. BUT YOU CAN'T GET SOMETHING FOR NOTHING!	Energy may be either released or absorbed when particles of matter interact.	The conversion of matter to energy demonstrated through use of simple arithmetic

PHYSICAL SCIENCE: IDEA FOUR (INTERACTION)

Matter and Energy Are Constantly Interacting, Producing Our Changing Environment

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. NOTHING IS FOREVER	Our surroundings are constantly changing.	Inspecting weather maps, sunspot photos, and moon photos
2. IT'S A BREEZE	Interacting heat energy and air cause wind.	Heating sand and water by radiation; blowing up a balloon with hot air; the Coriolis effect
3. IT'S NOT THE HEAT; IT'S THE HUMIDITY	Moisture in the air is controlled by interacting water, air, and energy.	Evaporating and condensing water; forming fog in a jar
4. WE WALK ON IT DAILY	Interacting matter and energy wear away the surface of the earth.	Cracking a jar by freezing water; fracturing plaster by embedded beans; reacting lemon juice with calcite
5. OUR GREAT BIG LAYER CAKE	Interacting matter and energy form new layers of the earth's surface.	Evaporating copper sulfate solution; examining fossils; forming sedimentary layers in a milk carton
6. GROW SOME ROCKS	Interacting matter and energy form new materials in the earth.	Melting, dissolving, and recrystalizing crystals; forming an insoluble substance by combining a soluble crystal with sodium silicate
7. WHAT GOES DOWN MUST COME UP	Interacting matter and energy raise and lower the surface of the earth.	Inspecting marine fossils from mountains; melting ice allowing floating board to rise; demonstrating isostasy in silly putty using metal cylinder
8. WHAT'S GOING ON DOWN THERE?	Energy waves give information about the earth.	Sending waves through springs; interpreting seismograph records
9. IT GETS LATE TOO EARLY	The amount of radiant energy reaching the earth changes regularly with time.	Analyzing fuel bills; measuring sun's angle; studying average temperatures
10. SOMEWHERE IN SPACE	Energy from objects in space is used to locate them.	Measuring angles and distances with range finder; parallax
11. THE STARS TELL ALL	Energy from objects in space is used to tell what they are made of.	Heating objects to incandescence; seeing through a prism the spectrum of ordinary light; observing through a grating solid and gaseous spectra
12. TURN RIGHT FOR SUNSHINE	The moving earth causes the energy changes that produce the seasons.	Illustrating the seasons at different latitudes with a sphere

PHYSICAL SCIENCE: IDEA FIVE (TECHNOLOGY)

Man's Understanding of the Interactions of Matter and Energy Allows Him to Control His Environment

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. YOU TURN ME ON	Switches let us control energy.	Operating simple switches and thermostats
2. BLOCK THAT BREEZE	We use matter to control the energy around us.	Insulating ice with paper; testing samples for thermal and electrical conduction
3. I MADE IT MYSELF	We are surrounded by a man-made environment.	Mixing concrete; making a urea-formaldehyde synthetic which will glue wood
4. THE FORCE TO MOVE MOUNTAINS	Useful work may be done when energy changes form.	Changing electrical energy to light, heat, and magnetism; making electricity with electrodes in salt solution and detecting it with an ammeter
5. IT'S DONE WITH WIRES	Magnetic energy may be converted to electrical energy.	Producing electricity by poking magnet and electromagnet inside a coil; blowing a 0.2 amp fuse
6. MOTORS TURN YOU ON	Interacting electricity and magnetism can do work.	Producing turning-forces by magnets and electromagnets; assembling and operating electric motor
7. YOU GET IT THERE AND LEAVE IT THERE	Transportation depends upon interacting matter and energy.	Investigating aerodynamics with paper strips and Ping Pong ball; studying inertia
8. MAKING THE BIG SOUND	Interacting electricity and magnetism can produce sound.	Assembling telegraph and speaker; investigating an earphone
9. SORRY, WRONG NUMBER	Sound may be converted to patterns of electrical resistance, making speech over long distances possible with wires.	Vibrating rulers and rubber bands; changing the current by changing the resistance; assembling microphone and using it with earphone
10. IT'S NOT FOR REAL	Understanding magnetic waves lets us send pictures through space.	Inspecting movie film; showing animation by flip-pictures; showing illusion of motion by string of lights; analyzing and reconstructing optical image
11. YOU HAVE TO STAY SHARP	An understanding of technological uses of matter and energy is needed to be safe in our man-made world.	Producing chlorine from household chemicals; burning nail polish, remover, and absorbent cotton; comparing the slipping ease of rubber-backed and plain carpets

How Is Inquiry Used to Teach Content in IIS?

The style and strategy of teaching IIS are extremely simple. Each investigation is designed so that the student, with the teacher's guidance, discovers one concept at a time. Each series of investigations is a sequential development of concepts. The selection of concepts and processes has been made in terms of the students' intellectual, social, motivational, and educational maturity.

The IIS approach uses a series of concrete experiences as a foundation on which concepts are built: *The student forms the concept; he does not receive it.* The IIS materials are tailored to the unique characteristics of the uninvolved student:

1. He cherishes his experiences because they are tangible to him. Also, he often has more patience with the mechanical details of laboratory experiments than gifted students do.
2. He can draw conclusions and formulate concepts better when he discovers these from his own practical experiences.
3. He learns well from group verbal interactions and personal experiences, but does not learn well from books.
4. He can comprehend related facts leading to the understanding of a larger idea, but soon forgets unrelated facts.
5. He likes to be challenged, but without pressure and within his capabilities. He enjoys the physical challenge of manipulating laboratory equipment.
6. He thrives on success.

The IIS program provides opportunities for the students to practice some of the same kinds of inquiry processes that scientists use in their investigations. The ideas of science are taught from an inductive-discovery approach. This approach also best meets the characteristic behaviors of the educationally uninvolved student.

Each time a learning experience is provided, it is built upon what has come before it and creates a "readiness" for the next learning experience. This readiness assures maximum "success experience" from the very beginning.

Science concepts are man-made and tentative, subject to constant evaluation, modification, and clarification. Much of the IIS program directs the students toward the processes and methods of seeking answers in the laboratory, rather than toward exact answers.

Ten major processes have been identified for use in the IIS program. These processes are common to all science programs that use inquiry to develop conceptual understanding. The terms associated with these processes are:

Observing
Classifying
Inferring
Predicting
Measuring
Communicating
Interpreting Data
Formulating Questions
Experimenting
Formulating Models

The descriptions that follow will help to clarify the meaning of these terms. Each description is also keyed to one example of many from the IIS program.

Process	IIS Example
Observing: Observations are made in a variety of ways using one, several, or all of the senses.	*Biology Idea 1, Investigation 2:* The students observe the behavior of a mealworm, sense the change of taste of a cracker, and try to figure out a puzzle.
Classifying: Classifying is the grouping or ordering of objects and events according to a scheme devised by the observer.	*Biology Idea 2, Investigation 7:* The student transfers morphological information about 15 animals to a set of data punch cards. The cards are coded, punched, and sorted to separate the animals into similar groups.
Inferring: An inference is a statement developed from a set of related observations. Inference requires evaluation and judgment.	*Biology Idea 3, Investigation 7:* After observing three generations of beans and peas, the student sees a second generation crop of tobacco seedlings and is asked to infer its parental background.
Predicting: Prediction is the formulation of an expected result based on past experience. The reliability of prediction depends upon the accuracy of past observations and the ability to make inferences from a set of observations.	*Physical Science Idea 2, Investigation 11:* Students repeatedly roll a marble down a ramp into a cluster of differently colored marbles. From the results of this experiment, they predict the nuclear structure of the atom.
Measuring: Measuring is the determination of the magnitude of selected properties. The units of measure can be arbitrary or standardized.	*Physical Science Idea 2, Investigation 3:* The student weighs H_2O first as ice, and then as water, to determine if there is any difference after a physical change.
Communicating: Communication is the process of describing, recording, and reporting experimental procedures and results to others. For clarity, tables and graphs may be used.	*Physical Science Idea 1, Investigation 10:* The student writes a paper describing what kind of ball rolls downhill the fastest.
Interpreting Data: The interpretation of data requires that a student assess the validity, precision, and usefulness of the data.	*Physical Science Idea 3, Investigation 3:* The student must interpret data generated by making measurements on the motion of pulleys and levers.
Formulating Questions: Questions are based on previous observations and usually precede attempts to evaluate a situation or event. They usually arise from inferences and give rise to predictions which must be tested.	*Biology Idea 3, Investigation 12:* After observing various patterns of inheritance, the student is guided to ask the question, "What and where are the 'bits of information' that influence the features received by an offspring?"
Experimenting: Experimenting involves designing data-gathering procedures and then gathering the data needed to test a prediction. Variables must be identified and controlled as much as possible.	*Biology Idea 5, Investigation 6:* The student tests germinating and nongerminating seeds to determine their relative rates of gas production.
Formulating Models: A model is a physical or mental representation of what the observer infers is the real object or event. Models are used to describe the interrelationships of concepts and ideas.	*Physical Science Idea 2, Investigation 6:* The students use popcorn and puffed rice to formulate a model of the particulate nature of matter.

How Is IIS Socially Relevant?

The IIS program is socially relevant in three important ways. First, Biology Idea 1 and Physical Science Idea 1 both develop the idea that science is man-made and is but one of the many activities of man. Second, scientific problems with social implications are considered. Third, the student becomes personally involved because he must make a value judgment on social problems.

To be relevant, a science course must be concerned with the relationships between science, technology, society, and the individual. IIS considers the following cultural implications of science:

1. *Aesthetic* beauty can come from the excitement of discovery and the simplicity of conceptual explanations.

2. Scientific endeavors are universal, without cultural or ethnic boundaries. They have a potential for developing bonds of common *philosophical* ideas between peoples of the world.

3. Science can thrive best under a government that is basically democratic. Many *political* decisions require scientific judgment.

4. Scientific and technological advances have a strong influence on *economic* development. In turn, a society's economic needs influence the rate of scientific and technological advance.

5. The rapid accumulation of scientific and technological knowledge has created a need for deeper insights into scientific-*sociological* problems.

IIS involves the student in an analysis of current scientific problems having social implications. Among the socially relevant topics the students discuss, analyze, and make judgments about are:

Socially Relevant Topic	Investigation
Automation	Physical Science Idea 3, Investigation 4
Drug Abuse	Biology Idea 4, Investigation 9
Education	Physical Science Idea 1, Investigation 8
Education	Biology Idea 1, Investigations 7 and 8
Employment	Physical Science Idea 1, Investigation 9
Home Safety	Physical Science Idea 5, Investigation 11
Information Explosion	Physical Science Idea 1, Investigation 10
Information Explosion	Biology Idea 1, Investigation 9
Natural Resources	Physical Science Idea 4, Investigation 7
Nuclear Testing	Physical Science Idea 2, Investigation 10
Nuclear Testing	Physical Science Idea 3, Investigation 8
Pollution (Noise)	Physical Science Idea 1, Investigation 11
Pollution	Physical Science Idea 3, Investigation 5
Pollution	Biology Idea 5, Investigation 10
Population Explosion	Biology Idea 2, Investigation 2
Racial Prejudice	Biology Idea 2, Investigation 12
Smoking	Biology Idea 4, Investigation 5
Space Race	Physical Science Idea 4, Investigation 10
Urbanization	Biology Idea 5, Investigation 9

Through these topics, the IIS program hopefully will provide the individual student with a deeper insight into his attitudes and values toward society.

What Is the IIS Matrix?

There are three levels of learning in the IIS program—concepts, processes, and values. The three levels of learning do not take place in isolation. Attitudes, cognitive processes, and concepts must be learned as a totality of human experience.

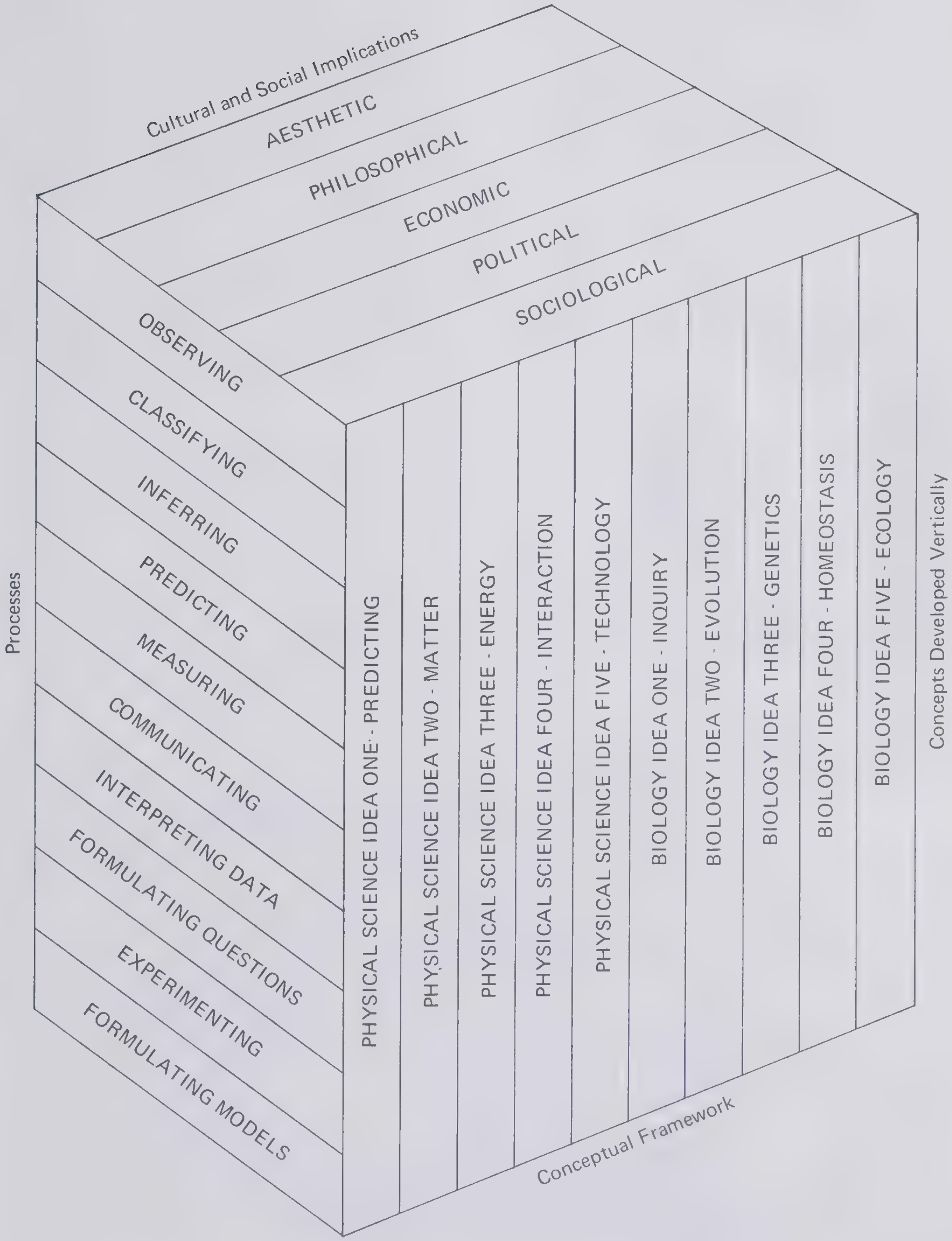
The IIS program forms a three-dimensional matrix which encompasses

a. the conceptual framework of science

b. the processes of science

c. the cultural and social implications of science

THE IIS MATRIX



How to Teach the Program

No extensive orientation is needed to teach IIS, but you must keep in mind that the student is the focal point of the IIS program.

Your introductory remarks to the class should make science sound interesting and easy. Keep all your remarks positive. The one most important thing you should say is that the students will succeed and have fun learning IIS.

It is one thing to tell students they will succeed; it is another to prove it. The following characteristics of the program and suggestions of procedure will help do so.

1. In each Idea, all of the investigations for one student are bound together in consecutive order. The student data sheets follow each investigation. (The data sheets are bound separately in the hardbound version.)

2. When the students arrive for the first investigation, distribute a Data File to each student. Explain that all work will be done in class and that the folder will be a convenient place to store lessons from day to day.

3. Point out to the students the inside back cover of the Idea titled, "IDEA SUMMARY." On this page the student is to maintain a running summary of the concepts discovered in each investigation. (For the clothbound edition, the IDEA Summary sheets are found in the Data Book.)

4. The first investigation in the Idea should be separated from the book before class. Distribute one to each student and indicate that the rest of the course will be similar. It may take a week before the students believe you, but tell them that they will be working on laboratory investigations one after another.

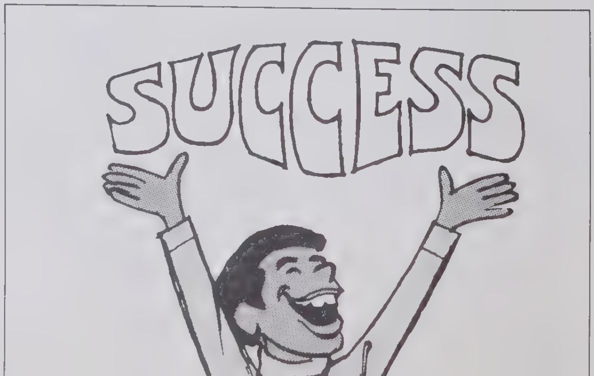
5. The IIS program is designed so that all of the work can be done in class. There is no need to give any exams, term papers, or homework, unless the teacher or student so desires. Impress upon the students that they have the ability to do all the investigations. They will be working in groups of two to four, but the results will be dependent on individual effort. You will be there to help them, but they will do most of the work themselves. With this combination, they are bound to succeed.

6. At the end of each class period, collect all the folders and keep them in a cabinet, on shelves in the classroom, or even in a cardboard box. It will not be necessary for the students to take their folders home. The rationale behind this is:

a. By doing the work in class, a 95% work turn-in can be realized. If the work has been done properly, a good grade should be given. Such performance and reward breeds confidence and success in a student.

b. The homework pattern of the uninvolved student is poor. If homework is taken home, the result is frequently a lost assignment or failure to do it. Homework is a phenomenon of the college-prep student and his future professional world. In the future world of most IIS students, there will be no homework. They will be judged by their performance on the job.

7. If you find it necessary to make rules at the beginning of the course, assure the students that the rules are simply to provide smooth operation of the course: If they are to succeed, they will want to have everything running smoothly *in their favor.*



The motivation you provide is of great importance in securing success for your students. The following techniques are useful:

1. The students should be praised every time an investigation is returned. Never take a negative attitude!

2. Never compare one student's paper to another. Instead, make suggestions as to how *all* the investigations can be improved. Remind students about the format for data tables, graphs, accuracy of measurement, correct English, and just plain neatness.

3. When you return an investigation, quickly summarize the activities performed, and then ask the students what concept they learned. When the class agrees on the concept, have the students enter this in the Idea Summary on the inside of the back cover.

4. Use visual aids to help the students see how the concepts are being developed sequentially. Each concept, as it is discovered, can be printed on cardboard strips and tacked to a bulletin board. Each new concept, as it is discovered, can also be unveiled with the use of an overhead projector. The students can then see daily where they have been, what they are pondering now, and where they may be going. Finally when the Idea is completed, they can see its overall development.

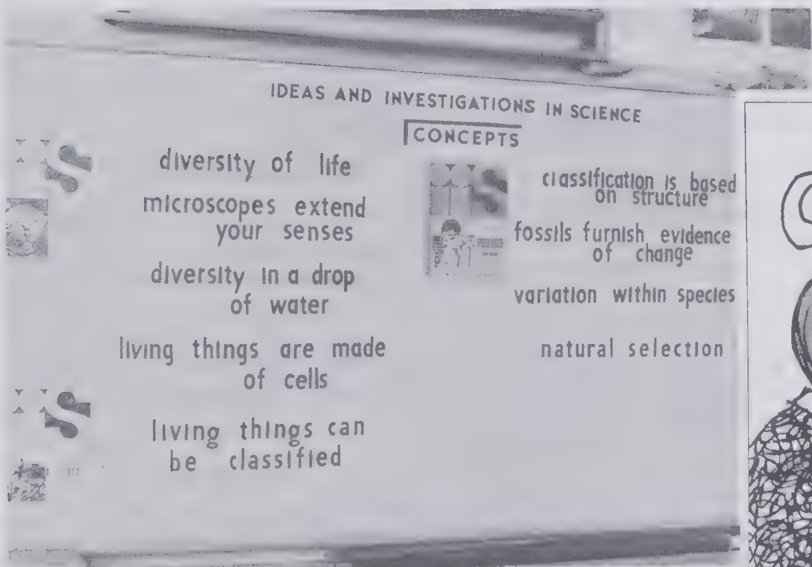
5. Before you start a new investigation, you should review all of the concepts studied previously. *Do not read the concepts.* Rather, summarize the data from each investigation and ask the students to draw the appropriate concept.

6. When you distribute an investigation, it may be necessary to read parts of the text and instructions to the students. You may need to demonstrate what has to be done, especially the set-up of equipment. You should even show and name the equipment because scientific and household equipment may be foreign to these students.

7. Many of the investigations are designed for groups of two students; in others, groups of four students are appropriate. You can keep these groups together as you circulate to assist, counsel, and "patrol." Become involved with the students in the laboratory and remove yourself from the front of the room.

8. Try not to answer questions. Instead, counter with other questions to assist the student in making his own discoveries.

The success of IIS does depend to a great extent on the attitude of the teacher. The role of the teacher in the IIS program is that of a helper and motivator. You must convey to the students your trust and faith in them. It will take a while for the students to realize that you believe in them. In the meantime, keep smiling!



How to Prepare Each Laboratory Investigation

IIS is designed with the average high school laboratory situation in mind. The laboratory used for the IIS program must have tables for the students to work on and the usual assortment of equipment and supplies; e.g., microscopes, balances, and glassware.

IIS is not an expensive laboratory program, since most of the items should already be available in any average-stocked science department. Items which are unique to the IIS program or are difficult to obtain are available through Prentice-Hall, Inc. Other items of a household nature can be obtained at the least expense locally.

A comprehensive list of materials needed for each level of IIS (Biology or Physical Science) is provided at the back of the Teachers Manual for that level. Use it as a guide to determine the materials you need.

Since almost every day in IIS is spent in the laboratory, the materials for each investigation should be organized in advance. The materials for each investigation are listed in the guide to that particular investigation. Materials are listed for each team of two (or four) students, so that if aides or assistants are available, they can be enlisted to prepare the materials needed for each team.

An easy way of organizing materials for each team of students is to place them in individual tote-trays. These can vary from fiberglass trays to dishpans, plastic trays, shoeboxes, cardboard box bottoms, and coffee cans. Laboratory preparation and dismantling can take place in a separate room and the trays be moved from class to class if necessary.

How to Use the Manual to Plan Each Day

The IIS program is structured in a step-by-step procedure which allows the student to experience a continued series of accomplishments. Each investigation is organized in a sequence of learning steps that help each student discover the concept of the investigation.

The organization of IIS provides students with the routine they need for a secure learning environment, but there is no monotony to this routine because there is variety in the activities from one investigation to the next.

Each investigation has its own unique characteristics, and you should read the portion of the Teachers Manual for each investigation. The following pattern is used in the Manual.

TITLE AND NUMBER: This identifies the investigation. The guide for each investigation can be easily removed from the Manual and put in a 3-ring binder with the investigation itself.

TIME: The times noted are for class periods of approximately 45-50 minutes and represent an average to above-average length of time. The times are given as an aid in planning, and you may not want to adhere to them.

REMINDER: These occasional reminders, indicated by the accompanying cartoon, refer to important details in the investigation or its preparation.

PURPOSE: This gives the concept to be developed in the investigation.

DEVELOPMENT: The development of each concept is stated in a few brief sentences. First, the laboratory activities are mentioned, and second, the discussion and questions that accompany the activities.

HIGHLIGHT: Each investigation has its own unique feature of special interest to the student. It may be a simple cartoon, game, laboratory experience, or a series of questions.

LOOK AHEAD: If an advance preparation is particularly necessary, it is noted here. The teacher should always be preparing an investigation or two ahead.

MATERIALS: The materials are listed for each team of two or four students or for the class as a whole. Materials needed by the teacher are also listed.

Preparation of Materials: The directions for the preparation of any special materials are given here.

TEACHING TIPS: This section comprises the main body of the guide for each investigation. It is divided into three subheadings.

Responses to Expect: Expected student responses and how to cope with them.

Practical Hints: An assortment of helpful hints.

Discussion and Review: Suggestions on how to handle the data and the questions that accompany each experiment.

ENRICHMENT: For those who find it necessary to assign extra work, a list of suggestions is given. However, you are cautioned to give extra assignments sparingly. If you have any students who finish early, give them the responsibility of helping to maintain the materials or of helping other students. The latter is especially valuable for them.

REFERENCES: This section is divided into two parts.

Books and Articles: Most of these references are for teacher background reading. You are, however, encouraged to keep reading material available for the students, too. Although uninvolved students are usually not interested in reading, you should encourage those of them who are.

Multi-Media Aids: These range from films to film loops, slides, filmstrips, overlays, special lab kits, records, and tapes. The sources are indicated. A list of distributors of these aids, with addresses, is provided at the back of the Teachers Manual for each level.

POSSIBLE ANSWERS: In many cases, no precise answer can be given; therefore only possible answers are listed. For convenience, these answers can be transferred to your copy of the student data sheet, or next to the question in the student text.

CONCEPT SUMMARY: Allow for considerable latitude in the way students express the concept.

What to Read for Background

Fantini, Mario D., and Gerald Weinstein, *The Disadvantaged: Challenge to Education.* New York: Harper & Row, 1968.

Frost, Joe L., and Glenn R. Hawkes, *The Disadvantaged Child: Issues and Innovations.* Boston: Houghton Mifflin, 1966.

Johnson, G. Orville, *Education for the Slow Learners.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963.

Passow, A.H., *Education in Depressed Areas.* New York: Teachers College Press, 1963.

Riessman, Frank, *Helping the Disadvantaged Pupil to Learn More Easily.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1966.

Strom, Robert D., *Teaching in the Slum School.* Columbus, Ohio: Charles E. Merrill, 1965.

Witty, Paul A., ed., *The Educationally Retarded and Disadvantaged.* Chicago: University of Chicago Press, 1967.

Idea 1
Inquiry

IIS BIOLOGY is divided into five Ideas, each of which is divided into a series of investigations developing an articulated sequence of concepts.

There are nine investigations in Idea 1. When the students finish, they will have discovered the major IDEA that:

SCIENCE IS AN ACTIVITY, A WAY IN WHICH MAN DISCOVERS MORE ABOUT HIS NATURAL WORLD.

The development of the concepts in Idea 1 can be seen at a glance by studying the middle column of the chart on the next page. Note that there are three main themes. Investigations 1-3 are concerned with the recognition of problems and their possible solutions. In Investigations 4 and 5, the student learns how to design a controlled experiment that will produce valid data. Then in Investigations 6-8, the student learns how to organize his data for study before drawing a conclusion. In Investigation 9, the student is given two open-ended problems and asked to use everything he has learned in the previous investigations to help him solve the problems.

Read the entire Teachers Manual for Idea 1 before beginning. All materials necessary for the nine investigations should be gathered beforehand. You should plan to stay at least two investigations ahead of the class in your laboratory preparations. If you haven't already done so, you are encouraged to read the Teachers Manual to the entire IIS program because there are many helpful hints throughout.

BIOLOGY: IDEA ONE (INQUIRY)

Science Is an Activity, a Way in Which Man Discovers More About His Natural World

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. WHATEVER TURNS YOU ON	A problem is recognized when a person senses something that does not agree with his mental ideas.	Discrepant events: lèmon and soda in tea; card blowing; chair lifting
2. MAN, WE NEED CHANGES	The recognition of problems depends on accurate observations.	Chewing crackers; mealworm observations; 9 square game
3. DON'T BE AFRAID TO GUESS	A scientist makes predictions to guide the solutions to a problem.	Germinating seeds wrapped in different plastics; guessing objects in sealed box
4. PETALUMA IS A SWINGING TOWN	Controlled experiments are run to test the predictions.	Analyzing breath for carbon dioxide; constructing controlled experiment
5. WEIRD HAROLD WEIGHS 45,500	Accuracy is improved when common units and numbers are used.	Creating units and determining length, weight, and volume
6. LET'S GET ORGANIZED	Results of experiments should be organized into data tables.	Measuring pupil size against light intensity
7. CAN YOU SEE AS WELL AS JOSÉ?	Graphs should be used to aid in the organization and interpretation of data.	Designing histograms, bar graphs, and line graphs
8. DO YOUR OWN THING	Conclusions must be based on the evidence collected.	Interpreting tables, graphs, and experimental data; observing weight changes in soaked seeds
9. IF IT'S HAPPENING, BABY, IT'S HAPPENING TO YOU	Science is an activity, a thinking process, used by man to solve problems about his natural world.	Two inquiry problems

BIOLOGY IDEA 1: INQUIRY, Investigation 1 (2-3 periods)

Test the tea needed for part A. Local water conditions may alter the results.

Find a small chair for use in part C which will be easy for a girl to lift but difficult for a boy. Test it first.

PURPOSE: Develop the concept that recognizing a problem is the first step toward solving a problem.

DEVELOPMENT: The students will observe the color change of tea when lemon juice is added, the failure of a card to move when blown, and the ease with which the girls can lift a chair that the boys cannot lift.

These discrepant events will cause a rise in curiosity, resulting in the recognition that problems exist.

HIGHLIGHT: After each activity, the students will be puzzled. But their hilarity and puzzlement rise to a crescendo when none of the boys can pick up a child's chair, whereas the girls have no trouble picking up the same chair (part C).

LOOK AHEAD: Obtain the mealworms needed for Investigation 2.

MATERIALS (for each team of two)

- Hot tea in a cup or beaker
- Dropper bottle of lemon juice or vinegar, or wedge of lemon
- Bicarbonate of soda (a pinch) or a dropper bottle of 0.01 *M* NaOH
- Stirring rod
- 3 x 5 inch index card
- Meter stick (optional)

MATERIALS (for teacher)

- Chair, small child's

Preparation of Materials

1. The teacher should always perform an experiment beforehand. The success of part A depends on the *p*H of the water, the strength of the tea, and the acidity of the lemon juice or vinegar. The addition of lemon juice or vinegar (*p*H 2.5-3.0) will lighten the color of the tea. The addition of bicarbonate of soda (or any base) will darken the color. If the local water is acidic, you may have to add some base to the water beforehand. Fresh spring water or soft water is excellent to use. It is usually more alkaline. Do not make the tea too dark.

If you cannot adjust the tea, substitute a straight acid-base activity. For this you will need 0.01 *M* NaOH, 0.01 *M* HCl, and phenol red solution.

To prepare phenol red solution, add 0.1 g of phenol red (phenolsulfonephthalein) to one liter of distilled water. Add 1-2 drops phenol red to a test tube of water. It should register yellow below *p*H 7 (acidic solution) and red above *p*H 8 (basic solution).

To prepare 0.01 *M* NaOH, dissolve 2 g NaOH in 500 ml distilled water. Take 100 ml of this solution and add water to make up a liter of 0.01 *M* solution. Keep the solution in a tightly stoppered container.

To prepare 0.01 *M* HCl, add 0.93 ml conc. HCl to make 1 liter.

CAUTION: ADD THE ACID SLOWLY TO THE WATER.

This same experiment can be varied by using red beet juice or juice boiled from radish peels or red cabbage. These substances simply serve as acid-base indicators.

2. Take a 3 x 5 inch index card and fold both short sides of the card one inch from the edge at right angles. Across the center of the card write, "Who wants to make a bet that you can't blow this card off the table?" Place the card on a table for the class to ponder. The folded edges will prevent the card from falling over.

3. Find a small chair for use in part C which will be easy for a girl to lift, but difficult for a boy (following the position directions in the text). A kindergarten chair is usually satisfactory. Read part C and test the chair first. Prepare a sign for the first day of school that reads, "Who can lift this chair the highest, a boy or a girl? Come to class tomorrow and find out." Tape this sign to the chair and place the chair on a table in full view of the class.

TEACHING TIPS

Responses to Expect: Every conceivable response of fear, anxiety, happiness, and anticipation will be present on the first few days of a new school year.

Since schools are usually involved with registration and orientation procedures on the first day of school, display the card and chair, described under Preparation of Materials, 2 and 3, while you are enrolling your students. This simple device will help set the attitude that science is an inquiring process. Curiosity, problem solving, and making discoveries are the key activities of the IIS approach.

Practical Hints: An excellent technique for opening the course is to ask the biggest boy (or the potential troublemaker) in the class to hold up the small chair (part C). After this is done with no effort at all, praise him for his strength. Cap this with a great big smile and he is sure to respond with an equally big smile. He's on your side!

You may want to repeat this same technique with some other boys in class. This is designed to mislead the class into thinking that the boys rather than the girls will have an easier time of picking up the chair in part C.

Thus you are creating a situation. When the students actually do the investigation, they will be so surprised at the result that they will stare in utter disbelief. You are trying to get the students to wonder, to question, and to recognize a problem.

When sufficient curiosity is aroused, distribute the IIS book or Investigation 1. (If necessary, develop the index card activity in a similar way before beginning Investigation 1.)

Read aloud the few sentences that precede part A. How much you read of this or future investigations depends on the reading abilities of your class. Regardless, read as much as possible of the first few investigations to insure initial success.

Since a small amount of lemon juice is used, usually only one drop, you may want to use a lemon wedge instead of lemon juice or vinegar. The lemon wedge can be reused in succeeding classes.

As the course progresses, the students will be working more and more on their own. But for now keep the class together. Have the students discuss and progress no further than questions 1 and 2. Then pass the bicarbonate of soda around the room. Discuss questions 3 and 4.

In part B, take the class vote needed for questions 5 and 6 before giving each pair of students an index card. The size of the index card is not sacred. Be sure to give someone in class the index card used as the motivating device. This will remove any suspicion that there is anything contrived about the card.

Direct the students to fold the two edges of the card at right angles to form a bridge. These cards can be reused by succeeding classes.

The sentence, "If you think you need a ruler to measure. . . ." appears in the text to lead the students into thinking they can blow the card a great distance. You may even want to pass out yard or meter sticks. It will add to their puzzlement when they're unable to budge the index card.

In part C, repeat the performance of having selected boys show how easily they can hold up a chair. By now, someone will probably have spotted the picture in part C, and noticed that the task is to be performed in a different way.

This is the best place to stop and take the class vote for questions 9, 10, and 11. The class will begin to show signs of wariness. That's good.

Always begin with a girl, preferably a slender one. Let two or three girls demonstrate how easy it is to pick up the chair following the rules in part C. The task will appear so easy that the class will begin to wonder "What kind of a Mickey Mouse activity is this?"

If you are a female teacher, carefully select your first male student to try and lift the chair. Be sure that he has a good sense of humor and is capable of taking a ribbing from his peers.

If you are a male teacher, use yourself as the first male subject. Let the class laugh at your inability to lift the chair. The boys in class will accuse you of "putting them on." There will be volunteers galore itching to prove that you're acting. Since they volunteered, they won't get mad when they are laughed at. The bigger and more broad shouldered the boy you select, the more difficult it will be for him to lift the chair. (Do not pick a tall, slender boy initially. He may be able to do it.)

Following the directions given in part C, the top-heavy boys will be unable to lift the chair. The bottom-heavy girls will easily lift the chair. The results are caused by the difference in body structure or center of gravity.

Discussion and Review: The key questions are "2," "4," "8," "13," and "14." All five questions are variations of the same theme, the ability to recognize and state a problem. Encourage the students to ask, "Why?"

The IIS program promotes the very essence of scientific enterprise. Your students are probably conditioned to accept authoritative statements. In your discussion, use the key questions to show that the method of science is to question.

The purpose of Investigation 1, as of all investigations in the IIS program, *is to develop a concept.*

Investigation 1 *is not* intended to teach about acids and bases (part A), Bernoulli's principle (part B), or the center of gravity (part C). You are certainly free to discuss these in class, if you wish, but do so only after the concept summary has been realized.

ENRICHMENT

1. Have the students write a paper on acids and bases, Bernoulli's principle, or the center of gravity.
2. Have the students start a collage of their impressions of science.

REFERENCES

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Hurd, Paul, "Toward a Theory of Science Education Consistent with Modern Science," *Theory into Action.* Washington, D.C.: National Science Teachers Assn., 1964, pp. 7-15.

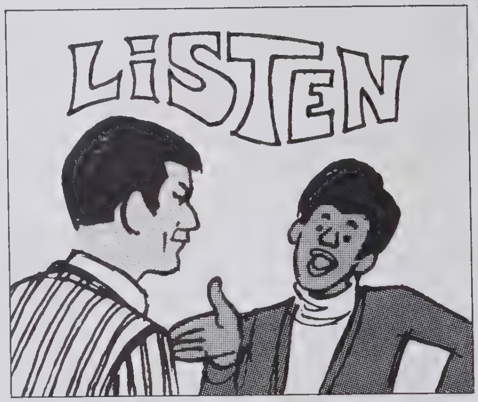
Rapport, Samuel, and Helen Wright, eds., *Science: Method and Meaning.* New York: New York University Press, 1963.

Sanders, Norris M., *Classroom Questions, What Kinds?* New York: Harper & Row, 1968.

Multi-Media Aids

Biology in Today's World: 16 mm, color, 11 min., Coronet 1326.

POSSIBLE ANSWERS



1. The tea turns lighter in color.
2. Why does the tea change color?
3. The tea turns darker in color.
4. Why does the tea change color?
5. (Class data)
6. (Class data)
7. No one. The card could not be blown away.
8. Why did the card stay in place?
9. (Class data)
10. (Class data)
11. (After part B, more students may vote for this category out of suspicion.)
12. The girls.
13. Why is it easier for the girls to lift the chair?
14. The problem.

CONCEPT SUMMARY: A scientist must be able to recognize problems.

BIOLOGY IDEA 1: INQUIRY, Investigation 2 (2-3 periods)

PURPOSE: Develop the concept that one must observe accurately in order to recognize problems.

DEVELOPMENT: The students will chew at length on a piece of cracker, observe the movements of a mealworm, and play a game called nine squares. The purpose of these activities is to test and sharpen a student's power of observation.

HIGHLIGHT: The highlight occurs in the game of nine squares, when the students realize (in a competitive situation) the value of careful observation in solving problems (part C).

LOOK AHEAD: The pea seeds for Investigation 3 should be wrapped in the plastic bags as described in the student text, part A, page 10.

MATERIALS (for each team of two)

- Cracker
- Mealworm, live
- Petri dish, plastic
- Paper towel
- Scissors
- Ruler

MATERIALS (for teacher)

- Water, 100 ml in beaker
- Vinegar, dilute, 100 ml in beaker[1]*
- 10% salt solution, 100 ml in beaker[2]
- Magazines, nine[3]

Preparation of Materials

1. To dilute the vinegar, mix two parts water to one part of vinegar.

2. To prepare a 10% salt solution, add 10 g salt to 100 ml water. Stir to dissolve.

3. Nine squares can also be played using a pattern of squares on a transparency or on the blackboard. See the illustration on page 7 in the student text.

TEACHING TIPS

Responses to Expect: The students will be tempted to swallow the cracker. Indicate that the purpose of the activity is to note any change in a chewed cracker. If necessary, mention flavor as a hint.

Before beginning the mealworm activity, give the students sufficient time to examine the mealworm. Expect squealing and disparaging remarks.

Practical Hints: In part A, the cracker will have a sweet taste after a few minutes. This is caused by the breakdown of starch into sugar by an enzyme secreted in the saliva.

A mealworm culture can be maintained by putting the mealworms in a nonmetallic, rust-proof container half filled with bran. A plastic or clay crock works quite well. Keep the culture in a dark, cool cabinet.

*Raised numbers following items in the Materials list refer to the next section, *Preparation of Materials*. Further information on the item will be found there.

Have the students observe a mealworm in the confines of an untreated Petri dish first. The following are some examples of what may be observed and reported:

a. a count of the body segments
b. a count of the number of legs
c. the manner in which it moves forward
d. the manner in which it moves backward
e. its reaction when it bumps into the edge of the dish
f. the paths it takes in one minute
g. the response when touched gently with a finger.

The curiosity of educationally uninvolved students is low, and their attention span is short. Don't expect any in-depth observations. Help the students to see more by giving occasional hints. Space *a* in the student data sheet can be used for this set of observations, and space *b* for the observations in part B.

When the mealworm is placed in the Petri dish treated according to the directions in part B, many other observations can be made. Examples include:

a. the speed over any particular section
b. the use of antennae
c. the frequency and length of time in a particular section
d. the paths taken in one minute
e. any differences in the way the mealworm moves over particular sections.

It is necessary for the teacher to explain the secret of nine squares to one student so that he can be IT. This student is to leave the room or turn his back to the magazines. The group selects one of the magazines for him to identify.

When the student collaborator who is IT returns, the teacher points to the different magazines, asking "Is it this one?" "Is it this one?" etc. The person who is IT will pick out the designated magazine.

The secret is to point to one of nine imaginary places on the first magazine. For instance, if the magazine designated is the one in the lower left-hand corner, point to the lower left-hand corner of the first magazine pointed to. The person who is IT then waits until the designated magazine is pointed out.

Another variation is for the person who is IT to wait until the teacher points to the spot on the designated magazine similar to its position on the floor.

Students who think they know the solution should be given an opportunity to be IT.

Discussion and Review: The last sentences in parts A, B, and C provide the thrust toward the concept. As each part is completed, emphasize these questions.

In these early investigations, it is recommended that the class discuss each question and decide as a whole on a consensus answer.

Question 4 is central to the understanding of the concept. Question 5 reviews the concept studied in Investigation 1, and then asks for the concept of this investigation. In other words, part D summarizes the concepts for both Investigations 1 and 2.

ENRICHMENT

1. Try additional observations on the behavior of mealworms, such as the response to:
   a. light, heat, color, or different foods
   b. a maze
   c. other mealworms
   d. different kinds of physical barriers.
2. Design some optical illusions for use in class.
3. Have the students do a paper on mirages.

REFERENCES

Books and Articles

Haney, Richard E., ed., *The Changing Curriculum: Science.* Washington, D.C.: Association for Supervision and Curriculum Development, 1966.

Malkin, Samuel, "The Culturally Deprived Child and Science," *Science and Children,* **1**: 5-7, April, 1964.

Nielsen, H. A., *Methods of Natural Science: an Introduction.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1967.

Romey, William D., *Inquiry Techniques for Teaching Science.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968.

Multi-Media Aids

A Story of Discovery: 16 mm, color, 13 min., Encyclopaedia Britannica 2464.

POSSIBLE ANSWERS

1. Salty or bland.
2. The taste became sweet.

Space *a* (The observations possible are so numerous that they can fill a book. What the mealworm does is secondary. How many different observations a student can make is the primary objective.)

3. The magazine chosen is designated by where the teacher points on the first magazine. For instance, if he points to the upper-left corner, it will be the upper-left magazine.
4. Observation.
5. Observe accurately.

CONCEPT SUMMARY: The recognition of problems depends on accurate observations.

Have the students wrap the peas according to the procedure described in part A before starting Investigation 3. If possible, do this on a Friday.

Whenever the words "store in a warm place" appear in the IIS program, they refer to constant room temperature.

PURPOSE: Develop the concept that predictions should be made to serve as possible answers to a problem.

DEVELOPMENT: The students make predictions about the germination of peas wrapped in two different kinds of plastic, and about the contents of a sealed box. From these activities, the students see that guesses or predictions give direction to the possible solution of a problem.

HIGHLIGHT: The mystery boxes prepared by the students enable them to see not only the importance of predictions, but also the necessity for educated predictions (part B).

LOOK AHEAD: There is a considerable amount of glass tubing to cut and prepare for Investigation 4. Start your preparation now.

MATERIALS (for each team of two)

- Plastic, polyethylene, 1 mil or 4 mil, 8 x 8 inches
- Plastic wrap, 8 x 8 inches (such as Saran wrap)
- Pea seeds, 20 (presoaked at least one hour)
- Paper towels
- String, about 10 inches, 2 pieces
- Shoebox
- Rubber bands
- Test tube, glass
- Marble, glass
- Petri dish, plastic
- Golf ball, plastic
- Pencil, wooden
- Block, wooden

TEACHING TIPS

Responses to Expect: Intelligent predictions cannot be made unless the student has an adequate background. Therefore, it is imperative that the student study the pictures on pages 9-10 carefully to recognize the problem. It is recommended that you explain the concept of germination.

The students seldom wet their towels sufficiently. Successful seed germination depends on adequate moisture.

Tie or bind the mystery boxes with rubber bands to deter the students from peeking inside.

Practical Hints: To insure added success in part A, wrap the pea seeds in two pieces of plastic food wrap. Squeeze all of the air out of the bag and tie the top securely. Check carefully to be sure there are no pin holes. Plastic wrap is impervious to air. The pea seeds in this bag will not germinate without oxygen.

Polyethylene plastic can be purchased in any hardware store. It comes in two sizes, 1 mil (0.001 inch) and 4 mil. Although it is more expensive to use two pieces of the 1 mil plastic, it is more consistent with the first hint. Air can permeate polyethylene plastic. Therefore, the seeds will germinate in this bag.

Presoak the pea seeds for 1-3 hours. Do not oversoak as this may cause peas in the plastic wrap to germinate.

Well-soaked vermiculite can be substituted for wet paper towels.

Store the bags in a place where room temperature remains constant. If the classroom is not heated at night and the temperature drops too low, install a light bulb or shine a desk lamp over the bags.

It is suggested that a marble and a test tube be put inside the mystery box in part B. If you have an exceptional class, add a wooden block. These items are used elsewhere in the IIS program, and they have a distinctive sound and shape. Do not put anything in the shoebox that is difficult to predict. The object is to give the student a good chance to make an accurate prediction.

For the mystery game that follows question 14, it is suggested that every group of students be given the last six items listed under Materials. These objects are suggested because they represent two different objects for each of three kinds of material. If you choose some other objects, make sure they have distinctive sounds, shapes, and names.

It is recommended that the students choose from the same six items supplied to every group. If the students know what objects can be put inside each box, they will have a basis for an educated prediction. This prevents wild guessing.

You must also watch the time. If you only have enough shoeboxes for one class, you will have to complete the use of the boxes in one period. Therefore, you might want to limit the objects to two per box, and the class competition to about eight boxes with a three-minute time limit on each box. Given five minutes to prepare the box, this should fit easily into one period. On the other hand, if you can collect enough shoeboxes (coffee cans, candy boxes, or cigar boxes will also do) for each class, you can proceed with much less tension.

Discussion and Review: Obtain a piece of plastic wrapping used by dry cleaners to cover clothes. Point out the label, "Warning: To avoid danger of suffocation, keep away from babies and children. Do not use in cribs, beds, carriages, or playpens. This is not a toy." You may want to show this to the class before they make their prediction in question 4. With this information, they are in a position to make a more intelligent guess and will be able to justify their explanation in question 5.

To supplement the text between question 7 and part B, you might want to prepare a set of humorous questions and answers. Mix them up and pass them out in class. Read the answer first and then the question. This device illustrates that an answer is useless unless you know the question.

The investigation is summarized in the text that follows the mystery box game. Discuss this in class.

ENRICHMENT

1. Germinate seeds under two different temperatures.
2. Germinate seeds under two different light conditions.
3. Have students write a paper on accidental discoveries. Are they accidental?
4. Compare the following words: predicting, hypothesizing, and inferring.

REFERENCES

Books and Articles

Medawar, Peter B., *The Art of the Soluble.* New York: Barnes and Noble, 1967.

Robinson, James T., *The Nature of Science and Science Teaching.* Belmont, Calif.: Wadsworth Publishing Co., 1968.

Taba, Hilda, "Strategy of Learning," *Science and Children,* **3**: 21-24, September, 1966.

Woodburn, John H., and Ellsworth S. Osbourn, *Teaching the Pursuit of Science.* New York: The Macmillan Co., 1965.

Multi-Media Aids

Observation: Filmstrip, Interaction Productions.

POSSIBLE ANSWERS

1. Why did one grass seed grow and the other grass seed die?
2. One is heavy and opaque. The other is thin and clear.
3. The plastic clings to the skin and if it covers the nose and mouth, the baby will suffocate. (The plastic is impervious to air.)
4. The ones wrapped in the thin, clear plastic will not sprout.
5. Seeds cannot grow without air.
6. Most of the seeds in the thicker, opaque plastic sprouted. None of the seeds in the thin, clear plastic sprouted.
7. The results compare favorably with the prediction.
8. Nothing, because the problem or question is not indicated.
9. He wouldn't know what you were talking about.
10. The problem is unknown to him.
11. The problem or question.
12. Predictions provide a basis for solving problems.
13. Wood, glass, plastic, metal, cardboard.
14. Test them to see if they were correct.
15. If you recognize where you are going, you will know you are there when you arrive.

CONCEPT SUMMARY: A scientist makes predictions to serve as possible solutions to a problem.

TABLE NO. 1

IDENTIFYING OBJECTS IN MYSTERY BOXES

Box	Number of Objects	1 Pt.	Kind of Objects (Glass, Metal...)	2 Pts.	Name of Objects (Bottle, Pencil...)	2 Pts.
A	3	1	plastic, glass, wood	0	ball, block, test tube	0
B	2	0	plastic, wood	0	dish, block, pencil	0
C	3	1	glass, wood, plastic	2	ball, pencil, test tube	2
D	3	1	glass, plastic, wood	2	marble, dish, block	0
E	3	1	plastic, glass, wood	2	ball, block, marble	2
F	3	0	plastic, wood	2	ball, block	2
G	3	0	wood, plastic, wood	2	ball, block, pencil	2
H	3	0	plastic, wood, glass	2	ball, tube, block	0
I						
J						
K						
	Subtotal	4		12		8
Grand Total	(add all three subtotals)		24			

BIOLOGY IDEA 1: INQUIRY, Investigation 4 (2 periods)

PURPOSE: Develop the concept that a prediction should be tested and that the test should be in the form of a controlled experiment.

DEVELOPMENT: The student is given two bottles of limewater and asked to test the prediction that he exhales carbon dioxide. In designing the experiment the student notes that he must pass carbon dioxide through only one bottle of limewater. This gives rise to the concept that a control or check is necessary.

HIGHLIGHT: The highlight is presented in the form of a puzzle. The student is given two bottles of limewater and an assortment of glass and rubber tubing. He is then told to connect everything together in such a way that the breath will bubble through one container while room air bubbles through the other.

MATERIALS (for each team of two)

- Glass container, about 1 pint
- Straw
- Limewater, 100 ml[1]
- Vinegar, 10 ml[2]
- Sodium bicarbonate, 1" in test tube
- Test tube
- One-hole stopper to fit test tube
- Glass tube, bent, to fit one-hole stopper
- Test tube rack
- Flasks, 125 ml or 250 ml, two
- Two-hole stoppers to fit flasks, two
- Glass tubing, 4", two pieces
- Glass tubing, 6", two pieces
- Rubber tubing, 10", two pieces
- Y-tube, glass or plastic

Preparation of Materials

1. To prepare the limewater, fill a container with water (a gallon jug is sufficient for a series of classes). Slowly add calcium oxide, shaking continuously, until no more will dissolve in the water. Let the excess calcium oxide settle to the bottom. Use the clear limewater.

2. To prepare the vinegar, mix in a 1:1 proportion with water or make a 3% acetic acid solution.

3. Insert a bent glass tube into each one-hole stopper as pictured in the text on page 14.

4. Insert two glass tubes into each two-hole stopper. All the student has to do then is to insert the rubber tubing in the proper place. The correct procedure is pictured in Possible Answers.

TEACHING TIPS

Responses to Expect: To prevent the students from cutting themselves, tell them not to move the glass tubing in the stoppers. Tell them you have already set the tubing in its proper place.

The student will be tempted to draw premature conclusions at certain places in the investigation. A good example is right after question 1. Seeing the limewater change, he will say that it was caused by the carbon dioxide in his breath, even though he has no proof or understanding of what is happening. It's as though the "magical" change had to explain something. Question 3 prevents such a premature conclusion.

Practical Hints: Put water in the two flasks when the students are searching for the correct way of connecting all the tubing. After you check the experimental setups, substitute limewater for the water.

It is suggested that you do this investigation in its three separate parts. Complete, clean up, and discuss each section before proceeding to the next.

Discussion and Review: Summarize the entire investigation by discussing both the illustrations before question 16 and part C.

ENRICHMENT

1. Have students bring in ads showing claims made without any controls.

REFERENCES

Books and Articles

Goldstein, Philip, *How to Do an Experiment.* New York: Harcourt, Brace & World, 1957.

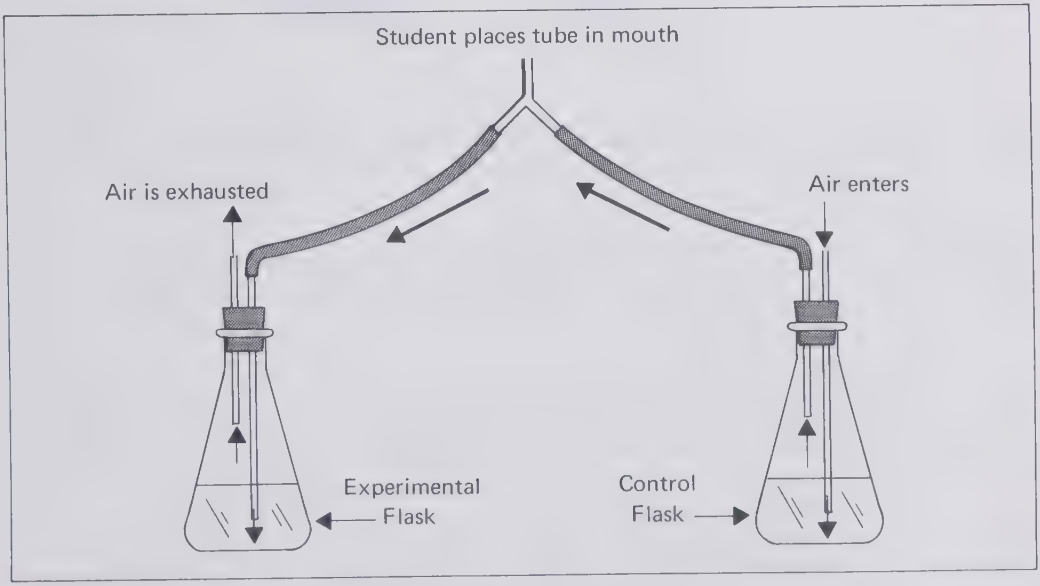
Kuslan, Louis I., and A. Harris Stone, *Readings on Teaching Children Science.* Belmont, Calif.: Wadsworth Publishing Co., 1969.

Suchman, J. Richard, "Inquiry Training in the Elementary School," *The Science Teacher,* 27, November, 1960.

POSSIBLE ANSWERS

1. It turns cloudy.
2. My breath. (Some may say carbon dioxide.)
3. No, because we do not know what gas(es) is (are) in our breath.
4. Bubble known carbon dioxide into limewater.
5. It turns cloudy.
6. Carbon dioxide.
7. Cloudy.
8. The bubbling action.

Drawing *a*



9. The breath will turn the limewater cloudy but the air will not.
10. No, because bubbles were in both containers and only one turned cloudy.
11. The one with the breath bubbling through it.
12. It would turn cloudy.
13. There is much more carbon dioxide in my breath than in the air. (Note the factor of control in the last four words.)
14. The containers, glass, rubber tubing, and bubbles.
15. The kind of bubbles or gas. My breath in one and air in the other.
16. The tube of water.
17. It lacked the factor being tested.
18. She does not have a control. To what is Linda comparing Petaluma?
19. To test predictions.
20. A controlled experiment.

CONCEPT SUMMARY: Predictions must be tested by controlled experiments.

BIOLOGY IDEA 1: INQUIRY, Investigation 5 (4-5 periods)

PURPOSE: Develop the concept that experimental accuracy can be enhanced by recording results in quantitative terms, and by using common units.

DEVELOPMENT: The student will make his own measuring stick, weigh himself on a metric bath scale, and make his own measuring cup.

From the measuring devices that he makes himself, the student will discover that the class must agree on a common set of units in order to communicate, and the calibrations of the devices must be accurate. Otherwise, the data collected will be useless.

HIGHLIGHT: In each of the activities, the students are asked to decide upon a common unit for their measurements. This repetitive device should impress them with the necessity for accurate measurements using common units.

MATERIALS (for each team of two)

- Piece of wood, about 3/8" x 1" x 10"
- Metric tape, pressure sensitive[1]
- Paper clip
- Index card, 3" x 5"
- Binder paper
- Bath scale, metric[2]
- Balance
- Wooden block
- Bottle of water
- Live mouse (optional)
- Erlenmeyer flask
- Jar, one quart or larger
- Tape, masking
- Graduated cylinder
- Straw, bendable, or piece of rubber tubing, 10"
- Pan or pail, large

Preparation of Materials

1. Although it is not as effective, you can substitute a metric ruler for the metric tape and piece of wood. Metric tape is supplied in the IIS equipment package. It can also be obtained from Macalaster Scientific (2637).

2. You can convert a bath scale marked in English units to one with metric units by opening the scale and recalibrating the dial. A metric bath scale is also available from Hickok Teaching Systems, Inc.

TEACHING TIPS

Responses to Expect: As we enter the more mathematical investigations, expect an increase in the amount of complaining. The students' lack of interest is a way of covering up or rationalizing their poor background in math. Try not to emphasize the math.

Because they have a poor command of the English system, the students will resist learning any new measuring system. Therefore, do not overemphasize the metric system. The concept of this investigation has to do with the *accuracy* of measurements, not learning another system of measurement. However, some familiarity with the metric system will be helpful in later investigations.

Practical Hints: You may wish to begin part A by giving the students the stick with a piece of masking tape on it. Then ask them to measure something, such as the width of a table. Allow the class to go through a period of confusion. If no one suggests it, drop a gentle hint that they can mark units on the masking tape. Anything will do to space out units: coins, clips, fingers, or pencils. After the students all measure a common object, collect the class data on the blackboard. From the confusion of the assorted data, hopefully, someone will suggest that the class use a common unit. This may be the right time to substitute the metric tape for the masking tape.

Do not assume that the students know how to write numbers in a decimal form. They are more familiar with fractions. Help them with decimals.

Question 3 (similarly questions 5 and 15) will present a dilemma. At this point in the course, all the student needs to know is centimeter. You can introduce millimeter and meter at a later time.

A paper clip, index card, and binder paper are suggested items for the students to measure as part of question 4. However, you may assign other objects, but do not assign anything that is too difficult to measure. The student already has the decimal system, an unfamiliar measuring stick, and a strange new word for a unit to contend with.

The students should weigh themselves on the bath scale with the metric units before answering question 5. Again, it would be best to use grams and kilograms. If you prefer to use another term, go ahead. Regardless, do not explain any terms other than gram and kilograms.

You will need about 6-8 items for all the students to weigh. In the materials list, the suggested items include a wooden block, bottle of water, paper clip, flask, and live mouse. These items are to be weighed by every group in the class, including one group with the bath scale. The data are to be recorded in question 6. The results should show that the weight of the same item will vary from group to group. This is caused by the sensitivity or nonsensitivity of the scale, and the competence of the person doing the weighing.

Prepare a measuring cup similar to the one prepared by the Girl Scout named Loretta in part C. Use a jar that is tapered. Apply a tape to the jar with lines that have been marked off at equal distances. Use this to illustrate the answer for question 11. The student should see that the tapered container will alter the volume indicated on the tape.

To prepare a measuring cup properly, it is necessary to measure a known volume in a graduated cylinder, and to use the known volume to calibrate an unknown container.

An ideal jar to use in part C is an empty acid bottle. A quart jar will also work since the amount of exhaled air will not exceed 300 ml. A quart milk jar is better than a large mouth jar. The smaller opening will help to keep water in the jar when it is turned over.

It will take more than one period to complete part C. The same jar can be reused from class to class by leaving the tape on the jar. There may be as many as 4-5 strips of calibrated tape on each jar, each labeled with the name of the respective student group.

In lieu of the bendable straw, you can use the pieces of rubber tubing from Investigation 4. They will have to be washed after each class, of course.

The purpose of question 19 is to show the student that even though his measuring jar is calibrated, the experimenter can affect the accuracy of the results. You can expect the students to exhale extra air into the measuring jar. This illustrates an error factor that they have introduced.

Discussion and Review: Practically all of the questions in this investigation are excellent for discussion. Remember, the discussion is to center around the concepts of measurement and accuracy, not the metric system. It really makes no difference what system the student uses as long as he is accurate.

The last four questions summarize the entire investigation.

ENRICHMENT

1. Have the students design a treasure hunt where measurements have to be taken to reach the prize.
2. Have the students do a paper on the history of measurement.

REFERENCES

Books and Articles

Conant, James B., *Science and Common Sense.* New Haven: Yale University Press, 1951, pp. 25-41.

Lovell, K., *The Growth of Basic Mathematical and Scientific Concepts in Children.* London: University of London Press, 1961.

Raths, Louis E., et al, *Teaching for Thinking–Theory and Application.* Columbus, Ohio: Charles E. Merrill, 1967.

Multi-Media Aids

Experiments with Length: Filmstrip, color, 41 frames, SVE 449-1.

Experiments with Mass: Filmstrip, color, 34 frames, SVE 449-2.

Experiments with Volume and Density: Filmstrip, color, 49 frames, SVE 449-3.

Measurement: Filmstrip, Interaction Productions.

Measuring Techniques: 16 mm or 8 mm film loops, color, 14 min., Thorne 33-1 and 33-2.

Weighing Techniques: 16 mm or 8 mm film loops, color, 8 min., Thorne 32-1 and 32-2.

POSSIBLE ANSWERS

1. 10.
2. 0.1.
3. (Try to get class to use centimeter.)
4. Paper clip, 3.4 cm; length of index card, 12.5 cm; width of binder paper, 21.2 cm; width of book, 16.2 cm.
5. (Try to get class to use gram.)
6.

Item	*Your Balance*	*Another Balance*	*Another Balance*	*Bath Scale*
Paper clip	impossible to get weight; too light	0.54	0.56	too light
Bottle of water	93 g	92.8	93.1	92
Wooden block	5 g	5.1	5.4	5
Flask, 125 ml	57 g	56.7	56.5	57
Pencil	5 g	4.8	5.2	5

7. It was different.

8. No, the clip is too light for the scale.

9. The balances were not adjusted correctly. The person doing the weighing did not know how to use a balance.

10. No; the sensitivity of the balance and the competence of the user.

11. No; the jar has tapered sides so the volume between marks is not the same.

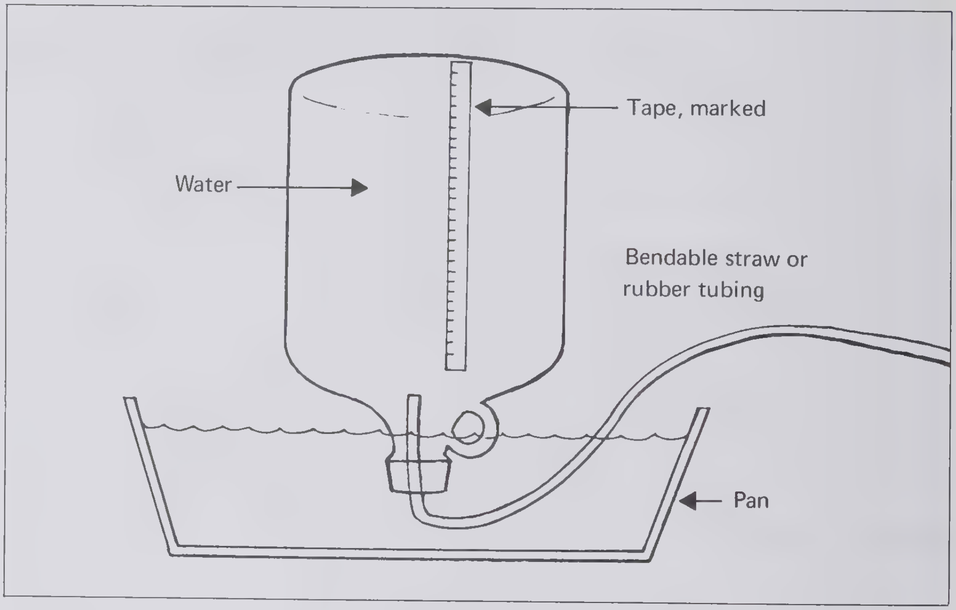
12. Pour measured amounts of liquid into the jar and then mark the tape accordingly.

13. 10.

14. 0.1.

15. (Try to get the class to use milliliter.)

Space *a*



16. It will be about a liter.

17. It will be about a liter.

18.

Your Average	167 ml	Another student, opposite sex	184 ml
Another student, same sex	193 ml	Another student, opposite sex	151 ml
Another student, same sex	205 ml	Another student, opposite sex	164 ml
Average	188.3 ml	Average	166.6 ml

19. The jar was tipped when line on tape was read. Student forced additional breath out. Some of the air escaped from straw.

20. Thinner than what? There is no control.

21. 45,500 what? There are no units.

22. Numerical form.

23. Units of measurement.

CONCEPT SUMMARY: Accuracy is improved when common units and numbers are used.

BIOLOGY IDEA 1: INQUIRY, Investigation 6 (2-3 periods)

PURPOSE: Develop the concept that experimental data should be arranged in a logical manner, preferably in the form of a table.

DEVELOPMENT: The students will read data from a preconstructed table. Then they will do an experiment measuring the size of the eye's pupil in relation to light intensity, and record their findings in a data table.

From these two activities, they will learn how to construct a simple data table.

HIGHLIGHT: The students learn certain facts about the pupil of the eye. This should stimulate interest in the experiment and emphasize the necessity of a data table for recording information (part B).

MATERIALS (for each team of two)

- Measuring stick or plastic metric ruler
- Flashlight
- Meter stick

TEACHING TIPS

Responses to Expect: To prevent confusion, turn the lights off and let the students walk into a dim room. By the time you finish taking the roll and explaining the experimental procedure for part B, the students will have adjusted to the dark and settled down.

In part B, the student must prepare the framework for the table before doing the experiment. Because the student has to design the data table first, he must plan his experimental procedure.

Practical Hints: Review the millimeter before proceeding to the experiment in part B.

Supplement the investigation by making transparencies of additional data tables. Find data tables from popular periodicals. These are the tables the students will see in their daily lives. Ask questions about the tables as they are projected to the class.

Review the structure of the eye. This will give the student the background necessary to make a prediction in question 10.

Do not distribute the ruler, flashlight, and meter stick until the student has designed his data table and shown it to you for approval.

Discussion and Review: Discuss the text on pages 23-24 with the class. It is a good review of the concept of experimental design and controls. At the same time, it gives the student a basis for designing a data table without telling him how to draw the table.

Ask the students to bring in tables cut from newspapers and magazines. Use these as further examples of how tables can be designed.

ENRICHMENT

1. Make a display of sample data tables cut from newspapers and magazines.
2. Make a data table with information concerning the local school population.

REFERENCES

Books and Articles

Arons, Arnold B., and Alfred M. Bork, *Science and Ideas.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Bronowski, J., "The Abacus and the Rose: A New Dialogue on Two World Systems," *Science and Human Values,* rev. ed., New York: Harper & Row, 1965, pp. 80-85.

Popper, Karl R., *The Logic of Scientific Discovery.* New York: Basic Books, 1959.

Multi-Media Aids

Classification: Filmstrip, Interaction Productions.

POSSIBLE ANSWERS

1. World swimming records for women's freestyle.
2. Debbie Meyer.
3. Los Angeles, California.
4. The world's record for the 200 meters is two minutes, six seconds, and 7/10ths of a second.
5. The 800 meters on August 28, 1968.
6. Average future lifetime of an individual born in the United States.
7. A white female.
8. The average remaining lifetime for all individuals in the United States at a particular age.
9. The average remaining lifetime for a nonwhite female between the ages of 40-45.
10. The pupil will contract as the light intensity increases and will expand as the light intensity decreases.
11. Test the prediction with an experiment.

Space *a* **EFFECT OF CHANGES IN LIGHT ON THE PUPIL OF THE EYE**

Distance from Eye to Flashlight, cm	Diameter of Pupil, mm
10	4
30	5
50	5
70	6
100	6
200	6
300	6

12. To organize information.
13. In a data table.

CONCEPT SUMMARY: Experimental data should be organized in a data table.

Review all previous concepts.

PURPOSE: Develop the concept that graphs can be used in the organization and interpretation of data.

DEVELOPMENT: The student will learn how to design three kinds of graphs: histograms, bar graphs, and line graphs. The student will use the graphs he has designed to plot data. He will then see how a pictorial version of the data is easier to visualize and interpret.

HIGHLIGHT: The wooden block activity reviews the concepts developed thus far, and provides an interesting background for the design of bar and line graphs (part C).

MATERIALS (for each team of two)

Ruler, metric
Meter stick
Probability device[1]
Wooden block, about 1 1/2" x 1 1/2" x 1 1/2", with 3/4" cup hook, six[2]
Screw hook, 1 3/8" long x 1/2" angle[3]
Mirror

Preparation of Materials

1. If you do not have an IIS equipment package, you should obtain the HEXSTAT® Probability Demonstrator, produced by the Special Projects Department of Harcourt, Brace & World, Inc.

2. Insert a cup hook into the center of one side of each wooden block.

3. Tape an angle hook to the end of each meter stick.

TEACHING TIPS

Responses to Expect: The students will probably complain about the large amount of math needed to complete this investigation. Numbers are the alphabet of science. Try to make the activity as interesting as possible by relegating the math to a secondary role.

Practical Hints: Help the students construct the framework for their histogram. Put this on a transparency and as each student has his height measured, have him put an "x" in the proper grid. In this way the class results will all be recorded in the histogram.

The mathematical basis of this investigation makes it a difficult lesson for the students. Treat each graph separately. Do not proceed to the next graph until the previous one is completely finished.

To cut costs, one wooden block instead of six will suffice. The student can pick up only one block at a time. Therefore, the one block can be reused six times in the experiment. The student serving as the timer can take the block off the hook and replace it on the table.

Help the students calculate the class average for questions 7 and 8.

Discussion and Review: The implications of the data in Table 1 have a significant social relevance. After the graphing is completed, discuss its significance.

Bring sample graphs cut from newspapers and magazines. Use these to illustrate the importance of organizing data.

ENRICHMENT

1. Prepare a display of the sample graphs brought in from newspapers and magazines.
2. Do a paper on Galton's probability "machine."

REFERENCES

Books and Articles

Braithwaite, Richard B., *Scientific Explanation.* New York: Cambridge University Press, 1953.

Youden, W.J., *Experimentation and Measurement.* Washington, D.C.: National Science Teachers Assn., 1962.

Multi-Media Aids

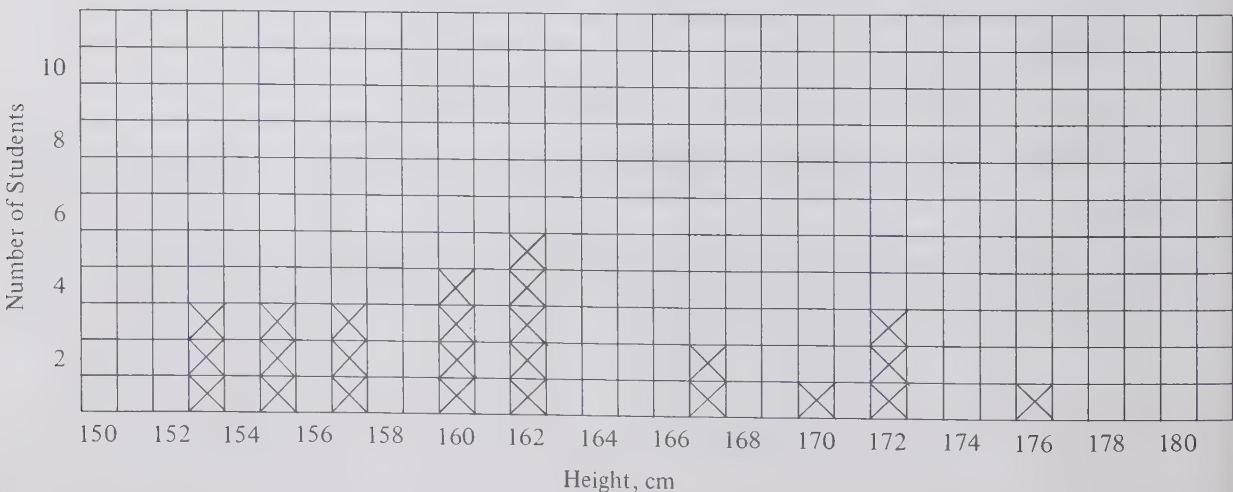
Big Things, Little Things–Concepts of Size: Filmstrip, color, 50 frames, Scholastic FSF11.

Order of Magnitude: Filmstrip, Interaction Productions.

POSSIBLE ANSWERS

GRAPH NO. 1

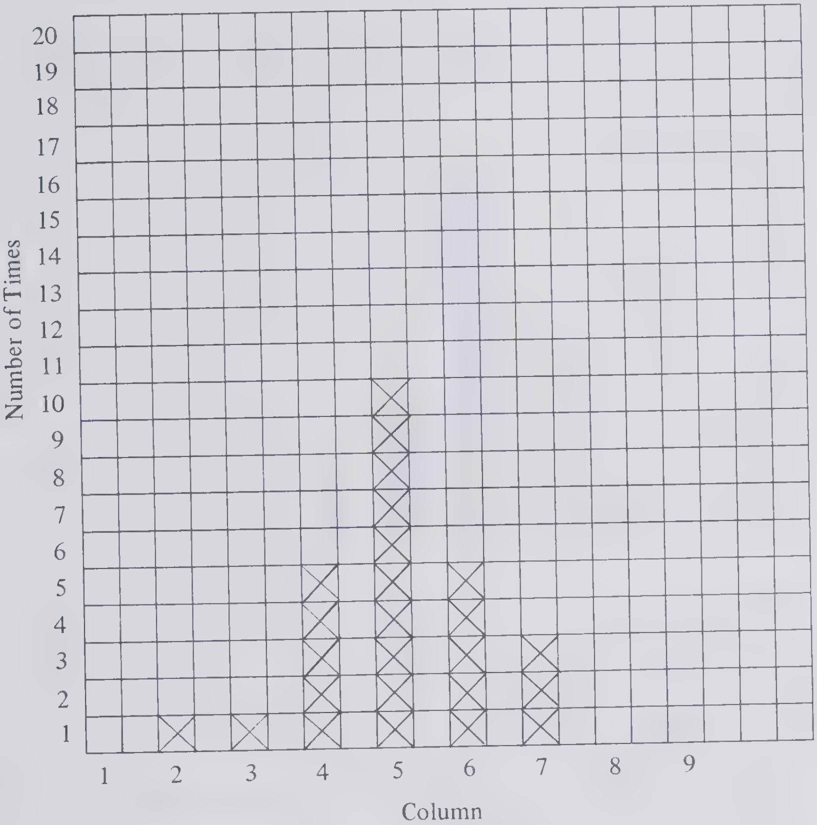
THE HEIGHTS OF STUDENTS IN A CLASS



1. Student prediction.
2. Obtain from histogram.
3. It helps him to see data in the form of a picture.
4. In the center column.

GRAPH NO. **2**

WHERE THE COLORED BALL FALLS IN A PROBABILITY GAME



5. The data confirm (or do not confirm) the prediction.
6. Student prediction.

Space *a*: Student calculations.

7. To be calculated.

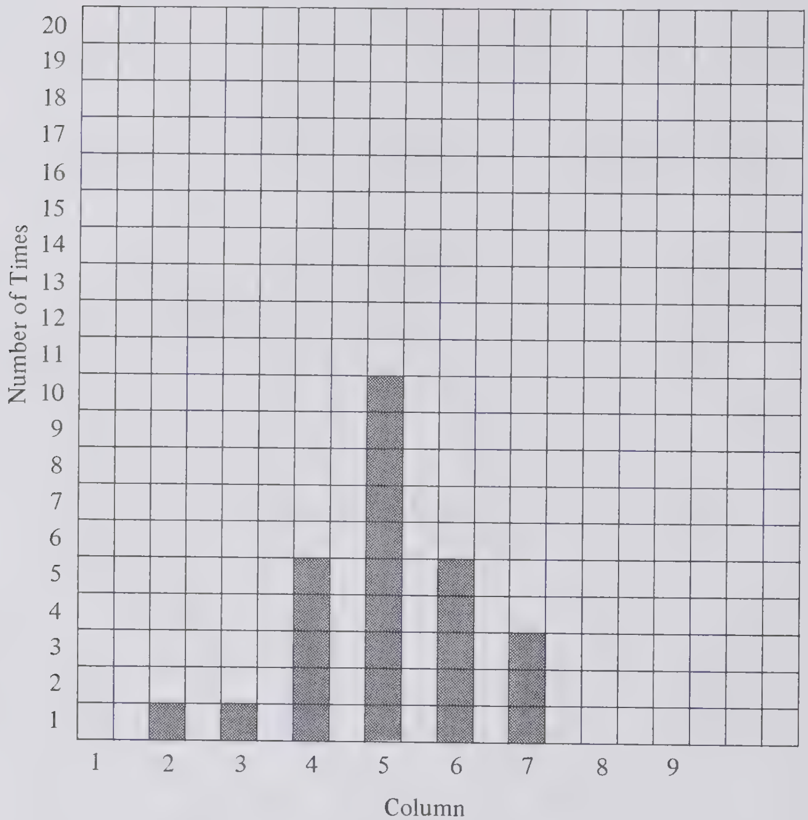
Space *b*: Student calculations.

8. To be calculated.
9. The results were below those predicted.
10. People think they can see better than they really can.
11. Yes. More blocks will be picked up each time.
12. The data confirm the prediction.
13. Graphs are used to display the data in pictorial form for easier interpretation.

CONCEPT SUMMARY: Graphs should be used to aid in the organization and interpretation of data.

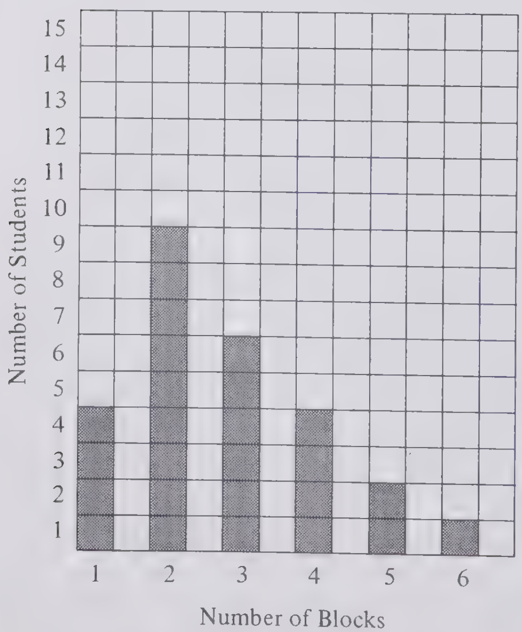
GRAPH NO. 3

WHERE THE COLORED BALL FALLS IN A PROBABILITY GAME



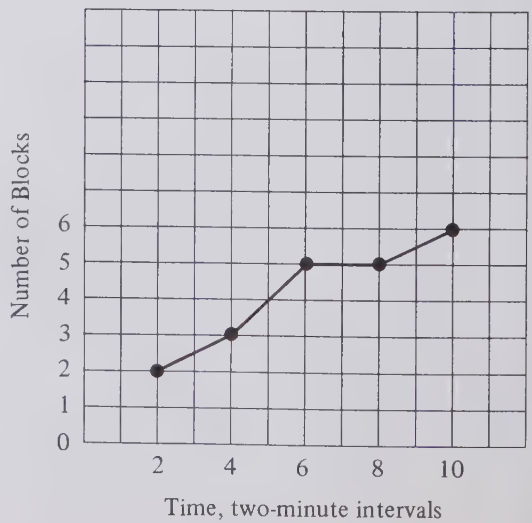
GRAPH NO. 4

THE NUMBER OF BLOCKS PICKED UP
IN TWO MINUTES BY A CLASS



GRAPH NO. 6

THE NUMBER OF BLOCKS PICKED UP IN
EACH OF FIVE TWO-MINUTE INTERVALS



BIOLOGY IDEA 1: INQUIRY, Investigation 8 (2-3 periods)

PURPOSE: Develop the concept that conclusions must be based on the evidence collected.

DEVELOPMENT: The students will analyze data from a series of graphs based on data previously collected, and from an experiment they will do themselves.

From these data, they will discover that they cannot overgeneralize. Otherwise, they will have insufficient data to support their conclusions.

HIGHLIGHT: In part C, the student is asked a series of questions about an experiment he has just done. Many of the questions cannot be answered from the available data. Can the student bring himself to say, "not enough data," or will he overgeneralize?

MATERIALS (for each team of two)

- Ruler, metric
- Radish seeds, five
- Okra seeds, five
- Jar, 1 pint
- Balance
- Paper towels

TEACHING TIPS

Responses to Expect: This is one of the most difficult investigations in the series. It not only requires that the student use much of what he has already learned, but it requires that he make decisions not always inherent in the data. The most relevant concept the student can learn is how to inquire on his own. Help him toward this goal.

Practical Hints: Explain and illustrate what is meant by a "best-fit" line. This should definitely be followed by a class discussion of the graphs on pages 32-33 of the text. Be sure the students understand and have the correct answers for questions 1, 2, and 3 before allowing them to proceed on their own. The rest of the investigation is dependent on their understanding of how to interpret a line on a graph.

Explain the five key statements that are to be applied to the graphs on pages 34 and 35 of the text. These require considerable thought, especially for a slower learner. You might have the entire class discuss and decide on the answers for questions 11 and 12, before allowing each student to proceed on his own.

The key to part C is in the use of okra seeds. The seed coat of an okra seed is so hard that it has to be physically cracked before imbibition will take place. On the other hand, radish seeds will take up water readily.

Before the students answer questions 20-26, point out the sentence *"If there is not enough data to answer the question, write in "not enough data.' "* This is the basis for the concept of this investigation.

Discussion and Review: After the students answer questions 20-26, you may want to go back and have a class discussion on the answers. Questions 23, 24, 25 cannot be answered from the data. These three questions provide the proper transition to part D, and to the concept summary.

ENRICHMENT

1. Have the students bring in ads to illustrate how claims are exaggerated.
2. Have the students bring in quotations cut from newspaper and magazine articles that are suspected of having insufficient proof.

REFERENCES

Books and Articles

Parker, J.C., and Louis Rubin, *Process as Content.* Chicago: Rand McNally Co., 1966.

Phenix, Philip H., *Realms of Meaning.* New York: McGraw-Hill Book Co., 1964.

Price, Derek J., *Science Since Babylon.* New Haven: Yale University Press, 1961.

Taba, Hilda, "Learning by Discovery: Psychological and Educational Rationale," *Elementary School Journal,* Chicago: University of Chicago Press, **63**: 308-316, March, 1966.

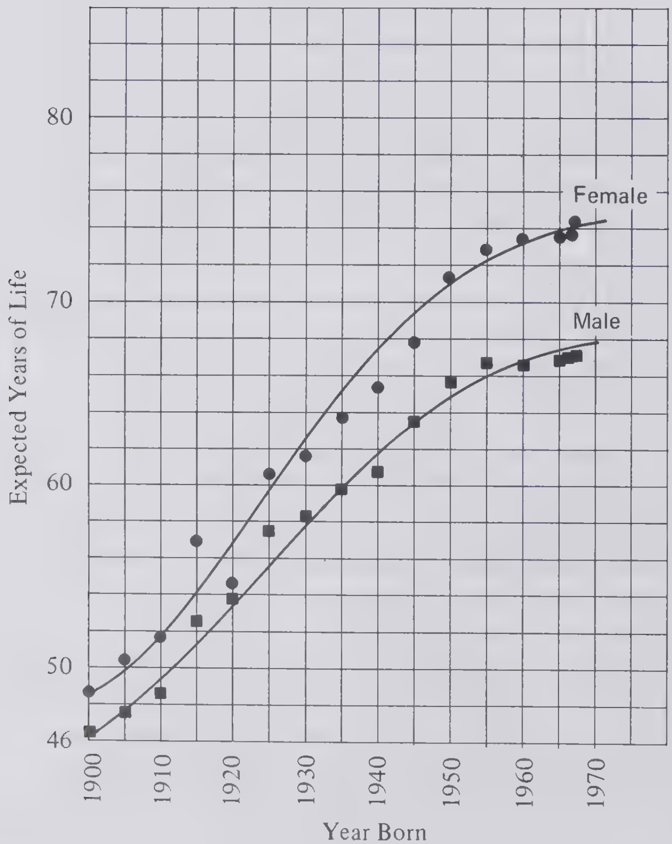
Multi-Media Aids

Perception of Life: 16 mm, color, 20 min., McGraw-Hill 407178.

POSSIBLE ANSWERS

GRAPH NO. 1

YEARS OF LIFE EXPECTED AT BIRTH



1. Increases.
2. Increases.
3. Does not change.
4. 67.9 years.
5. Female.
6. 68.7 years.
7. Since 1950 and 1955 are known, find 1952 on the line, and read the life expectancy.
8. 85-90 years.
9. Females.
10. They are living proportionately longer.
11. b.
12. b.
13. c.
14. e.
15. e.
16. e.
17. d.
18. a.

Space *a* THE WEIGHT OF FIVE RADISH SEEDS AND FIVE OKRA SEEDS, BEFORE AND AFTER SOAKING FOR 24 HOURS IN WATER

Seed	Weight Before Soaking, g	Weight After Soaking, g	Weight Change, g
Radish	0.14	0.20	0.06
Okra	0.36	0.38	0.02

19. They will increase. They will decrease. They will not change. The radish will increase and the okra will not change.
20. Radish.
21. Okra.
22. Absorption of water.
23. Not enough data.
24. Not enough data.
25. Not enough data.
26. Failure of the water to penetrate the "tough skin."
27. Refuse to draw a conclusion.
28. Makes sure he has sufficient data to support his conclusion.

CONCEPT SUMMARY: Conclusions must be based on the evidence collected.

BIOLOGY IDEA 1: INQUIRY, Investigation 9 (2-3 periods)

PURPOSE: Summarize all of the concepts (studied in the previous investigations) to develop the idea that science is a method of thinking used by man to discover more about his natural world.

DEVELOPMENT: The student will put to use everything he has learned from the previous investigations to solve one of the two problems that are suggested.

In the process of solving a problem, the student will experience the inquiry attitude of science.

HIGHLIGHT: This investigation provides an opportunity for the student to use what he has learned in Idea 1, by designing and carrying through one of the suggested activities.

MATERIALS (for each team of two)

Since this is an open-ended investigation, the materials needed will depend on the problem the student chooses to solve. If the student elects to investigate one of the two suggested problems, the following materials are needed:

Behavior of a Bug

Micro-biome, Scientific Manufacturing Industries 7150, *or*

Cockroach race track, Macalaster Scientific 54590

Plastic boxes, hinged, to fit cockroach race track (see illustration under Practical Hints), two

Cotton

Silica gel or anhydrous calcium chloride (or any desiccant)

Black construction paper or aluminum foil

Sow bug or mealworm

Testing Foods for Starch

Lugol's solution, in dropper bottle

Spot plate, test tube, glass caster, or any surface to test the foods

Assorted foods (bread, meat, fruit, milk, eggs, baby foods, cereals. . .)

TEACHING TIPS

Responses to Expect: The thought of attacking a problem alone may psychologically overwhelm the student. Perhaps, social and educational forces have conditioned the student to think that he is incapable of solving problems. Yet if one considers the numerous barriers this so-called slow student has had to surmount, his ability to solve problems far exceeds the ability of many others. Therefore, although we would like the student to solve the problem put before him, we have a far greater responsibility to him. We owe him the opportunity to develop an identity, a respect, and a belief in himself as a human being capable of fulfilling his potential. To accomplish this, provide him with all the necessary materials and general directions to complete the experiment.

Practical Hints: Bring some journals to class and let the students see the storehouse of science. It is not uncommon for students, and even occasionally science teachers, to think that the products of science are bombs, napalm, germ warfare, electric toothbrushes, and birth control pills. The product of science is knowledge. The purpose of Idea 1 and this investigation, in particular, has been to develop the idea that scientific knowledge is discovered in an orderly process.

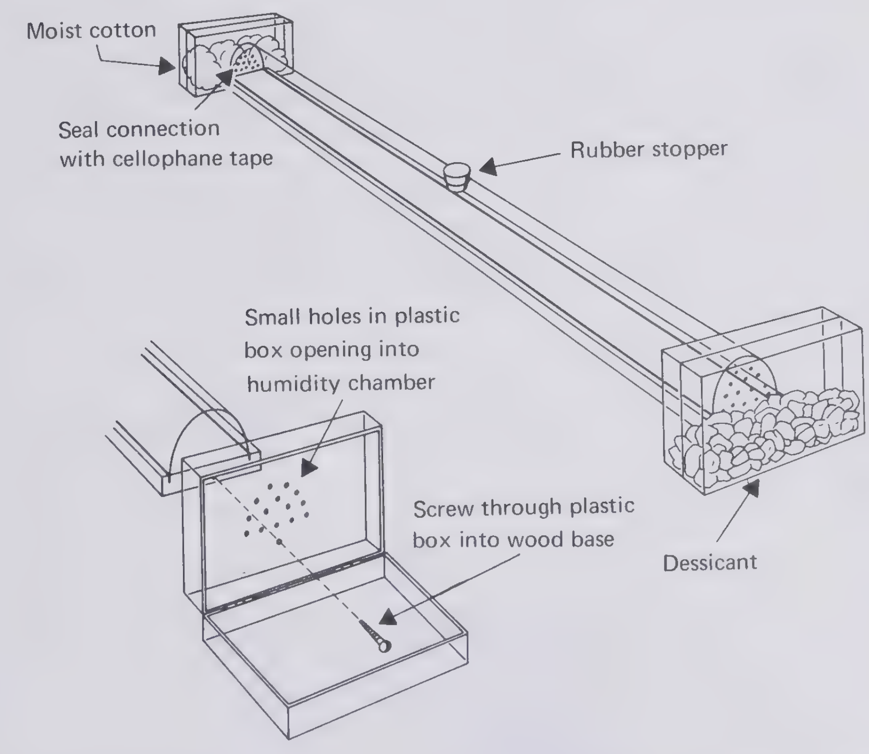
Of the two problems suggested in part A, the study of the bug's behavior is more difficult. The challenge to the student is far greater, but his understanding of inquiry is more deeply developed.

The testing of various food substances is almost a technical problem, rather than a scientific problem. However, the advantages offered by the latter problem include: (1) less expensive materials, (2) completion in a shorter time duration, (3) more predictable and definitive results, and (4) easier for the student to solve. Since the degree of complexity offered by the two problems is significantly different, you can best judge which is more appropriate for your class.

The ideal animal to use in studying the behavior of the bug is either a sowbug or a mealworm. The former can be found very readily under a rock or pieces of wood where it is moist. The latter may still be available in the classroom from Investigation 2.

Instructions on how to use the Micro-biome, made by Scientific Manufacturing Industries, are in the manual which accompanies the apparatus. Additional research problems are also given in the manual.

If you choose to use the cockroach race track, you will have to modify it by adding a plastic box to each end as shown.



The moist cotton and desiccant must be placed in opposite ends of the humidity chamber (the Micro-biome or the race track) 24 hours prior to its use, so that a humidity gradient can be set up.

Do not leave the stopper open for any length of time when introducing the bug. To remove the bug, turn the apparatus upside down, shake the bug near the stopper, remove the stopper, shake the bug out, and quickly replace the stopper to maintain the humidity gradient for the next class.

The starch test is fairly simple. Add 2-3 drops of Lugol's solution to the food to be tested. Look for a blue-black color. This color can be matched to a control. The ideal control is a sample of cornstarch.

Many students have a preconceived idea of which foods contain starch. To prevent them from anticipating their data, put out jars of baby foods with the labels removed.

Discussion and Review: The entire Idea is summarized in parts B and C.

ENRICHMENT

1. The student can do both of the suggested problems.
2. The student can do an additional problem of his own.

REFERENCES

Books and Articles

Bronowski, Jacob, *Insight: Ideas of Modern Science.* New York: Harper & Row, 1966.

Bronowski, J., *Science and Human Values.* New York: Harper & Row, 1965.

Hawkins, David, "Messing About in Science," *Science and Children,* 3: 5-9, February, 1965.

Maslow, Abraham H., *The Psychology of Science.* New York: Harper & Row, 1966.

Segal, Earl, and Warren J. Gross, *Physiological Adaptation.* Boston: D.C. Heath, 1967.

Shamos, Morris H., "The Role of Major Conceptual Schemes in Science Education," *The Science Teacher,* 33: 27-30, January, 1966.

Multi-Media Aids

The Web of Wonder: Sound filmstrip, color, Eye Gate 3A.

POSSIBLE ANSWERS

1-6. Student description of experiment.

CONCEPT SUMMARY: Science is an activity, a thinking process, used by man to solve problems about his natural world.

IDEA SUMMARY: Science is an activity, a way in which man discovers more about his natural world.

Idea 2
Evolution

You have just completed Biology Idea 1: *Inquiry*. Four ideas in the biological sciences will now follow. Each Idea will be a sequential development of concepts.

The IDEA Summary of the concepts discovered in Idea 2 is:

THE GREAT DIVERSITY OF LIFE HAS COME ABOUT BECAUSE LIVING THINGS HAVE BEEN CHANGING THROUGH TIME.

Ideas are not specific facts to be memorized. An idea may be stated in a slightly different form each time it appears, but it is always basically the same. Use the form most comfortable for you and your students.

Idea 2 is developed from the investigations and concepts on the next page. As you study the chart, notice that there are three main themes. Investigations 1-4 are concerned with the concept of diversity. In Investigations 5-7, the student sees that similarities are found in the diversity of life. And finally, in Investigations 8-12, he sees how natural selection has led to evolutionary change.

Read the entire Teachers Manual for the Idea before beginning. Each investigation is an integral part of the sequential development of the entire Idea.

BIOLOGY: IDEA TWO (EVOLUTION)

The Great Diversity of Life Has Come About Because Living Things Have Been Changing Through Time

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. YOU CAN'T HELP BUT BUMP INTO ONE	There are many different kinds of living things (diversity).	Photographs showing diversity
2. DON'T CALL IT DIRT	There are many different kinds of life in soil.	Isolation of organisms from soil
3. HUMAN SENSES ARE SO POOR	Microscopes extend the senses to help us see the great diversity of life.	Use of the microscope
4. WHAT'S SO COMPLICATED ABOUT WATER?	There is a great diversity of life in a drop of water.	Observation of organisms in water
5. ALL MEN ARE CREATED EQUAL	Despite the diversity of life, all living things are made of cells.	Observation of various cells
6. IS THERE ORDER TO CHAOS?	Living things can be arranged into related groups (classification).	Grouping cards and cutouts
7. PUNCH CARD A YELLOW-BELLIED SAP-SUCKER?	Order in classification is based on body structure.	Sorting data punch cards
8. YOU CAN'T SEE THE FOREST FOR THE ROCKS	Fossils furnish evidence for living things in prehistoric days.	Making fossil replicas
9. A HORSE, IS A HORSE, IS A HORSE?	Fossils furnish evidence that living things have changed through time.	Graphing growth of horse
10. VARIETY IS THE SPICE OF LIFE	There is variation within each species.	Graphing pea size, leaf length, reaction distance
11. SURVIVAL OF THE FATTEST	Nature selects the fittest to survive.	Selecting out colored cutouts
12. PEOPLE ARE BEAUTIFUL	Skin coloration is the result of natural selection.	Reading on origin of skin coloration

BIOLOGY IDEA 2: EVOLUTION, INVESTIGATION 1 (1 period)

PURPOSE: Develop the concept that there are many different kinds of living things on earth.

DEVELOPMENT: The students will write a morphological description of ten different organisms and conclude that they are all different. The student will then apply this conclusion to the question, "How did such a great diversity of life come to be?"

HIGHLIGHT: Question 12 directs the students to see the diversity in their descriptions, and thus the diversity in life.

LOOK AHEAD: Start preparations for Investigation 2 now. Reserve microscopes for Investigation 3. Order or obtain the organisms for Investigation 4.

MATERIALS (optional)

Colored slides or filmstrip
Preserved specimens

TEACHING TIPS

Responses to Expect: The students are sure to ask about each organism pictured. Tell them about the organisms and guide them to describe the organisms in morphological terms.

Many students will respond to question 12 by saying that all the organisms are alive. Ask them if they have proof for this statement.

Practical Hints: Don't forget to praise the students for how well they did in the first Idea and to express confidence in their future work in Idea 2.

Show a collection of colored slides or preserved specimens of various organisms to illustrate diversity. Live plants and animals will create even more interest. If possible, take the students on a field trip to the zoo or the botanical gardens.

Class discussion, particularly of the questions, should be used most of the time. Every student should be given a good start at the beginning of each Idea.

Do not dwell at length on this lesson. The concept of diversity will be reinforced in the next three investigations.

Discussion and Review: The concept developed will be the basis for the question, "How did such a great diversity of life come to be?" It will require the next eleven investigations to provide an answer. End the lesson on this question.

ENRICHMENT

1. Have the students prepare displays that show the diversity of life by size, shape, mode of locomotion, color, type of food, and location of habitat. The latter should include life in an urban center.

REFERENCES

Books and Articles

Worth, C. Brooke, and Robert K. Enders, *The Nature of Living Things.* New York: Signet Science Library, 1964.

Multi-Media Aids

The Protists: Film loop, color, Ealing 81-5928/1.

Animals Breathe in Many Ways: 16 mm, color, 11 min., Bailey-Film Associates 16-100.

Animals Hear in Many Ways: 16 mm, color, 12 min., Bailey-Film Associates 16-212.

Animals Move in Many Ways: 16 mm, color, 11 min., Bailey-Film Associates 16-23N.

Animals See in Many Ways: 16 mm, color, 13 min., Bailey-Film Associates 16-47.

POSSIBLE ANSWERS

1. Koala bear: brown, furry, black nose, small eyes.
2. Fir tree: needle-like leaves, shaped like a cone; large, main central trunk.
3. Lobster: two large arms with pincers, feelers coming out of head, curved tail, many legs.
4. Earthworm: many segments, smooth band near front end, round and long like a slender tube.
5. Bat: two wings, brownish fur, two distinct ears and eyes.
6. Canary: covered with feathers, beak on head, curved claws for feet, two legs.
7. Spider: eight legs, two body parts, long, thin legs.
8. Salmon: no legs, fins, covered with scales, large eyes.
9. Paramecium: shaped like a slipper, almost colorless.
10. Rhinoceros: horn in head, grey skin covering, four legs, heavy-set.
11. All the organisms were described by how they looked.
12. Each description was different.
13. There are many, many different kinds of living things.
14. There are many different kinds of living things.

CONCEPT SUMMARY: There are many different kinds of living things on earth.

Do Investigation 3 concurrently with this investigation.

This investigation may be optional without interrupting the flow of concepts.

PURPOSE: Develop the concept that there are many different kinds of living things in soil.

DEVELOPMENT: The students will isolate several different kinds of organisms from a small quantity of soil. Thus, they will see that soil is a viable environment for microorganisms.

HIGHLIGHT: The highlight of this activity is when the student sees the variety of life forms in soil.

MATERIALS (for each team of two)

Part A

Handful of moist garden litter crawling with insects

The Bug Betrayer apparatus:

- lamp (40 watts or more)
- funnel
- coarse mesh wire screen to fit inside funnel
- jar
- water or alcohol
- magnifying lens (optional)

Part B

Handful of moist, fertile soil

The Worm Wangler apparatus:

- funnel
- rubber tubing
- pinchclamp
- cheesecloth square, 8" x 8"
- string
- jar
- water

Part C

Pint or quart jar
Fertile soil
Hay or straw

Part D

Stagnant pond or aquarium water, preferably green with algae
Soil from the same pond or aquarium
Balance
Weighing paper or wax paper squares
Spoon, small chemical
Graduated cylinder, 100 or 250 ml
Pint jar or flask
Eyedropper
Liquid fertilizer, such as Ortho-gro

Part E

Fertile garden soil
Balance
Weighing paper or wax paper squares
Spoon, small chemical
Graduated cylinder, 100 ml or larger
Pint jar or flask
Petri dish of potato-dextrose agar with rose bengal and streptomycin added[1]
Eyedropper

Part F

Petri dish of nutrient agar[2]
Eyedropper
Soil water (from part E)
Microscope, slide, and cover slip
Masking tape or labels

Preparation of Materials

1. For potato-dextrose agar supplemented dishes: Measure 1 liter of cold water (tap water will do) into a pot. Add 39 g of potato-dextrose agar to the water. Add 0.3 g rose bengal stain. Heat to boiling, stirring occasionally.

Add one drop of streptomycin to each Petri dish. Pour 20 ml of agar into each dish.

Sterilization is not necessary, but is recommended. If you sterilize the media, you can autoclave in a pressure cooker at 15 lbs for 15 minutes. If you do not sterilize the media, wash the Petri dishes in hot soapy water, Phisohex, or Hexol. Then rinse in boiling water and turn upside down to drain on a paper towel. Add the agar and refrigerate. Use within 24 hours.

2. For nutrient agar dishes use the procedure above, *except* add 23 g of nutrient agar to 1 liter water.

TEACHING TIPS

Responses to Expect: Students will ask for the names of all the organisms isolated. The fact that you probably don't know all the names is another indication of the great diversity of life.

The students may want to know how "The Bug Betrayer" works. The heat from the light bulb dries the ground materials, driving the organisms down into the jar.

Practical Hints: As an opening, give each group of students some soil and have them note how it is seemingly devoid of life. Although the student instructions indicate that they will be given the soil material, you may prefer to have the students bring in soil from various sources.

Do not allow the mechanical procedures to overshadow the purpose of the investigation–to develop a concept. For this reason, read the instructions, show the students what to do, and circulate around the classroom to help them quickly complete the procedures.

Each part is designed to isolate specific organisms. They are:

A. insects and other arthropods
B. nematode worms
C. protozoans
D. algae
E. mold
F. bacteria and actinomycetes

Investigation 2 is done concurrently with Investigation 3. Both investigations require a total of seven days to complete. If possible start Investigation 2 on Monday and follow the schedule below:

Monday: Start Investigation 2, parts A and C with one-half of the class and B and C with the other half.

Tuesday: Start parts D, E, and F.

Wednesday: Start Investigation 3.

Thursday: Continue Investigation 3 and observe the results of Investigation 2, parts A and B.

Friday: Finish Investigation 2, parts A and B. Finish Investigation 3.

Weekend: Needed for additional growth of cultures.

Monday and Tuesday: Finish Investigation 2, parts C, D, E, and F.

It is recommended that half of the student pairs do part A and the other half do part B. This will reduce the amount of material needed.

Discussion and Review: In discussing the results of the experiments, do not dwell on the scientific names of the organisms. Anecdotes on each, of course, would be most interesting. Don't lose sight of the ultimate concept: there is a great diversity of life in a tiny bit of soil.

CAUTION: In all probability, the growth in every dish is harmless. However, to be safe, autoclave all plates before washing.

ENRICHMENT

1. Have the students collect and test samples from various locations. Correlate the data between environments and frequency of organisms.
2. Prepare a display on "soil ecology."
3. Prepare a report on molds and their contribution to antibiotic drugs.

REFERENCES

Books and Articles

Alexander, Martin, *Introduction to Soil Microbiology.* New York: John Wiley & Sons, 1961.

Bear, F. E., *Earth: The Stuff of Life.* Norman, Okla.: University of Oklahoma Press, 1962.

By Their Fruits. Merck Sharp & Dohme Research Laboratories, 1962.

Farb, Peter, *Living Earth.* New York: Harper & Row, 1959.

Garrison, Webb, "He Discovered Healing in the Soil," *Today's Health,* March, 1970, p. 42.

Gilman, J.C., *A Manual of Soil Fungi.* Ames, Iowa: Iowa State University Press, 1957.

Gray, W. D., *The Relation of Fungi to Human Affairs.* New York: Holt, Rinehart & Winston, 1959.

Prescott, G. W., *How to Know the Fresh Water Algae.* Dubuque, Iowa: Wm. C. Brown Co., 1964.

Multi-Media Aids

Life on a Dead Tree: 16 mm, color, 11 min., Bailey-Film Associates 16-21N.

Collecting Protozoans: 8 mm film loop, color, Encyclopaedia Britannica 80158.

Different Kinds of Molds: 8 mm film loop, color, Encyclopaedia Britannica 81180.

Sterilization of Laboratory Glassware: 8 mm film loop, color, Encyclopaedia Britannica 81174.

POSSIBLE ANSWERS

Space *a:* Student drawing.

1. The organisms look like bugs or insects.

Space *b:* Student drawing.

2. The organisms look like tiny worms (nematodes).

Space *c:* Student drawing.

3. Tiny, clear, moving organisms (mostly protozoans).
4. The liquid turned green (algae).

Space *d:* Student drawing.

5. There are fuzzy spots on the food material in the dish (molds).

Space *e:* Student drawing.

6. There are whitish, slimy looking spots on the food material in the dish (bacteria).
7. Soil was used in each part of this investigation.
8. The life probably came from the soil.
9. Many different kinds of living things.
10. Soil is a community of living things; "dirt" does not indicate life.
11. There are many different kinds of living things on earth.
12. There are many different kinds of living things in the soil.

CONCEPT SUMMARY: There are many different kinds of living things in the soil.

BIOLOGY IDEA 2: EVOLUTION, Investigation 3 (3 periods)

PURPOSE: Develop the concept that the microscope helps us to see many different kinds of living things.

DEVELOPMENT: The student will learn how to use a microscope, and will then use the microscope to examine the materials prepared in Investigation 2.

HIGHLIGHT: The students are given a thorough and systematic approach to the use of the microscope by means of numerous illustrations and clear directions.

LOOK AHEAD: Order or collect your live specimens for Investigations 4 and 5.

MATERIALS (for each team of two)

- Microscope
- Glass slide
- Cover slip
- Small piece of classified section of newspaper
- Scissors
- Eyedropper
- Small container of water
- Lens paper
- Metric ruler, transparent
- Paper towels
- Sand crystals

TEACHING TIPS

Responses to Expect: Students generally approach the use of the microscope with enthusiasm. However, in their eagerness to succeed, they may be inclined to rely on the accurate observations of a few. Try to have all the students involved by giving as much individual help as possible.

Practical Hints: Hold up a container of water and ask the students if they think there are any living things in the water. Ask them how they would find out. This should bring up magnification.

Microscopic technique is not the primary lesson. Emphasize the microscope as an instrument which helps us to see the great diversity of life.

Have the entire class proceed together through the handling of the microscope and the preparation of the initial wet mount. Students will need help in focusing a ruler under the microscope (part E).

Discussion and Review: Since the microscope is used frequently in the IIS program, it would be well to discuss most of the questions from 10 on. Resolving questions of a mechanical nature now will save time and improve accuracy in subsequent investigations.

ENRICHMENT

1. Have the student make his own magnifier. Place a drop of melted glass over a hole punched at the end of a tongue depressor.
2. Prepare a chart showing the history of the microscope.
3. Have the students compare the diameters of different types of hair.

REFERENCES

Books and Articles

Gray, Peter, *The Use of the Microscope.* New York: McGraw-Hill Book Co., 1967.

Multi-Media Aids

Microscope Techniques: 8 mm film loop, color, Ealing 81-0879/1.

Microscopy and Microbiology: Printed originals or transparencies, color, 23 visuals, 3M Company 15-0794.

POSSIBLE ANSWERS

1. 10x.
2. Usually 4x, 10x, 40x.
3. 40x (4x times 10x) or 100x (10x times 10x).
4. 400x.
5. To face and reflect the light to your eye.
6. The amount of light changes.
7. As little as possible. The sample should be thin, so as not to obstruct the light.
8. A drop of water added to the object on a slide.
9. It holds the slides together; excludes air; aids magnification.
10. Individual student response.

Space *a:* Student drawing.

11. The "e" should be upside down and backwards in the drawing.

Space *b:* Student drawing.

12. Magnification of the "e" is greater, but not all of it is in the field of the microscope.

Space *c:* Student drawing.

13. The opposite direction.
14. It disappears.
15. Less, because a smaller section (in the center) is being magnified larger.
16. The clarity (resolution) decreases as the magnification increases.
17. No. If an object is almost clear, it will not show up under very bright light.
18. Probably 1.6 mm.
19. Individual student responses.

CONCEPT SUMMARY: Microscopes help to extend the senses so that we can see many different kinds of living things.

BIOLOGY IDEA 2: EVOLUTION, Investigation 4 (2 periods)

PURPOSE: Develop the concept that there are many different kinds of living things in water.

DEVELOPMENT: The students will examine various samples of water and find additional forms of life. They will add this knowledge to the concept of Investigation 1, "There are many different kinds of living things on earth."

HIGHLIGHT: If the various water samples are teeming with life, student interest will be extremely high.

LOOK AHEAD: Prepare a yeast culture and obtain some *Elodea* for Investigation 5.

MATERIALS (for each team of two)

- Microscope
- Glass slide
- Cover slip
- Lens paper
- Paper towels
- Dropper bottle of methyl cellulose (optional)
- Dropper bottle of methylene blue or Congo red[1]
- Samples of pond water with eyedropper in each (scattered around the room)[2]

Preparation of Materials

1. To prepare methylene blue or Congo red, use the amount of powder on the end of a toothpick in about 100 ml of water. You want a medium dark solution. The exact amount is not critical.
2. Cultures of pond water or mixed protozoa can also be purchased from biological supply houses.

TEACHING TIPS

Responses to Expect: Unless you are a very good protozoologist, be prepared to say, "I don't know." The life forms in the various samples will be many and varied.

Practical Hints: The first four investigations set up the question for the entire Idea. Therefore, do not stress the morphology or taxonomy of the organisms. Instead, raise the question, "How did the diversity of life come to be?"

Ask the students to bring in their own samples of water. They will be more motivated if it is their own contribution to the class. Their excitement will be proportional to the quality of the pond water.

Before the students start on their own, you should:

a. Caution the students about getting stains on their clothing.

b. Remind them that the diaphragm should not be wide open because translucent protozoans can often be seen best against a dark field.

Methyl cellulose can be used to slow down rapidly moving organisms. This will enable students to make more detailed observations.

Stress the importance of careful drawings. Untidy drawings should not be accepted. However, time-consuming, detailed drawings are not necessary, either.

Identifying the various organisms is not important, although a drawing is furnished for those who are curious.

Discussion and Review: In discussing the investigation, there are two points to stress:

a. The process: Drawings are a form of data and as such should be done accurately.

b. The product: The concept that there is a diversity of life in a drop of water.

ENRICHMENT

1. Have students measure and compare the rates of locomotion of various organisms. If necessary, review the diameter of the field studied in the last investigation.

2. Prepare a display showing the diversity of life by size.

REFERENCES

Books and Articles

Disraeli, Robert, *New Worlds Through the Microscope.* New York: Viking Press, 1960.

Jahn, T. L., *How to Know the Protozoa.* Dubuque, Iowa: Wm. C. Brown Co., 1949.

Needham, James G. and Paul R., *A Guide to the Study of Fresh Water Biology.* San Francisco: Holden-Day, Inc., 1962.

Pimentel, Richard A., *Invertebrate Identification Manual.* New York: Reinhold Pub. Corp., 1967.

Simon, Harold J., *Microbes and Men.* New York: McGraw-Hill Book Co., 1963.

Multi-Media Aids

The Protist Kingdom: 16 mm, color, 14 min., Bailey-Film Associates 16-120.

Collecting Protozoans: 8 mm film loop, color, Encyclopaedia Britannica 80158.

World of Little Things (Life in a Drop of Water): 16 mm, color, 14 min., Moody Institute of Science.

POSSIBLE ANSWERS

Space *a:* Student drawings.

1. Many different kinds of living things.
2. There are many different kinds of living things on earth.
3. There are many different kinds of living things in water.

CONCEPT SUMMARY: There are many different kinds of living things in water.

BIOLOGY IDEA 2: EVOLUTION, Investigation 5 (2 periods)

PURPOSE: Develop the concept that living things are made of cells.

DEVELOPMENT: The students will examine various specimens and determine that they all have cells. They will see that despite the great diversity of life, all living things have at least one thing in common.

HIGHLIGHT: The cheek cell activity will add a personal element to the concept development (part C).

LOOK AHEAD: If you do not have an IIS Shape Kit, prepare the cutouts for Investigation 6.

MATERIALS (for each team of two)

- Microscope
- Glass slide
- Cover slip
- Lens paper
- Paper towels
- Toothpicks, two
- Dropper bottle of 2% salt solution[1]
- Dropper bottle of methylene blue[2]

MATERIALS (for class)

- Yeast culture[3]
- A few strands of *Anacharis,* also called *Elodea*[4]
- Assorted prepared slides showing cells

Preparation of Materials

1. To prepare salt solution, dissolve 2 g salt (NaCl) in 100 ml water.

2. To prepare methylene blue, dilute prepared stain to a very light blue, or dissolve a pinch of powder (0.25 g) in 100 ml water.

3. To prepare the yeast culture, mix 1 package of dry yeast in 500 ml water containing 100 g brown sugar. Stir and keep on a warm shelf overnight.

4. *Anacharis (Elodea)* can be obtained in any aquarium store.

TEACHING TIPS

Responses to Expect: The student may find some of his observations overwhelming because of the multitude of structures. The prepared slides with their many-colored stains may confuse him too. Be prepared to give a few initial pointers.

Practical Hints: As an opening, discuss the meaning of the title, the picture of the two boys, and the caption that follows. Although the intention is biological, the sociological implication of racial equality is evident.

Keep the *Elodea* in water at all times.

Use prepared slides that show cells rather obviously. Onion root tip cells are always good.

Stress the importance of accurate drawings as a means of recording data.

Discussion and Review: The students have seen diversity. Now the question becomes, "Is there any order to all this diversity?" Ask the students what they saw in each section of this investigation. They will say, "cells." Ask them if the cells were all from the same kind of organism. From this discussion, the students will infer that all living things are made of cells.

This is another example of order in science. Despite the diversity, there is order to all life forms. They are made of cells.

The question, "Do living things have anything else in common?" will provide the proper transition to Investigation 6.

ENRICHMENT

1. The student has only seen three to five examples. He is asked to infer an answer in question 6. Allow him to look at more samples. Excellent specimens include onion skin, leaf epidermis, prepared blood slides, and thin slices of cork.

2. Prepare a display showing the different kinds of human cells.

REFERENCES

Books and Articles

Asimov, Isaac, *View from a Height,* Part I: Biology. Garden City, N. Y.: Doubleday & Co., Inc., 1962.

McElroy, William D., and Carl P. Swanson, *Modern Cell Biology.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968.

Mercer, E. H., *Cells: Their Structure and Function.* Garden City, N.Y.: Doubleday & Co., Inc. (Anchor Books), 1962.

Schneider, Leo, *You and Your Cells.* New York: Harcourt, Brace & World, 1964.

Multi-Media Aids

From One Cell: 16 mm, color, 14 min., American Cancer Society.

Protoplasmic Streaming in a Plant Cell: 8 mm film loop, color, Encyclopaedia Britannica 81193.

Generalized Plant Cell: Prepared slide with instruction sheet, Ward's 93 W 2134.

Generalized Animal Cell: Prepared slide with instruction sheet, Ward's 93 W 2200.

POSSIBLE ANSWERS

Space *a:* Student drawing (Check for correct labeling of cell wall and cytoplasm.)

1. A cell.

Space *b:* Student drawing (Check for correct labeling of cell wall, chloroplast, and nucleus.)

2. A cell.

Space *c:* Student drawing (Check for correct labeling of cell membrane and nucleus.)

3. A cell.

Spaces *d* and *e:* Student drawings (Check labeling of structures in the prepared slides.)

4. Cells.
5. A cell.
6. Cells.

CONCEPT SUMMARY: All living things are made of cells.

BIOLOGY IDEA 2: EVOLUTION, Investigation 6 (2-3 periods)

PURPOSE: Develop the concept that living things can be arranged into related groups.

DEVELOPMENT: The student will sort playing cards, cardboard cutouts, and pictures of animals into related groups.

The student will see that although every card, cutout, and picture is different, similarities can be found. This leads to the inference that organisms can be arranged into related groups.

HIGHLIGHT: By manipulating and grouping animal cards into logical categories, the students will begin to see the order in animal diversity. A special feature of this activity is the student freedom to choose appropriate groupings (part C).

LOOK AHEAD: If you do not have an IIS equipment package, order the data punch cards needed for Investigation 7.

MATERIALS (for each team of two)

Deck of playing cards (optional)

Deck of animal picture cards from the academic game, *Classification* (See pages 72-73 for explanation of the preparation and use of the animal cards.)

IIS Shape Kit (Hickok Teaching Systems)[1]

Preparation of Materials

1. If you do not have an IIS Shape Kit, you can prepare cardboard cutouts from colored construction paper as follows:

Shape	*Color*	*Size*	*Total Number*
Triangle	Blue, red, green, yellow	1½, 2, 2½, 3"	4
Hexagon	Blue, red, green, yellow	1½, 2, 2½, 3"	4
Trapezoid	Blue, red, green	1½, 2, 2½"	3
Circle	Blue, red, green	1½, 2, 2½"	3
Rectangle	Blue, red	1½, 2"	2
Square	Blue, red	1½, 2"	2
Star	Blue	1½"	1
Diamond	Blue	1½"	1

TEACHING TIPS

Responses to Expect: The students will have a tendency to group everything on an "either-or" basis. For instance, "those with feathers and those without feathers." Encourage them to broaden their categories.

Practical Hints: Hold up a deck of cards and ask if the cards are all different or similar. Since most students are familiar with cards, you will probably get two immediate responses: (1) "All 52 are different," and (2) "Some of the cards are alike." Let the students keep responding. Gradually guide them to see the similarities of different groups of cards. Then have them complete Table 1.

Part B should be completed and discussed before proceeding to part C. It would be helpful to draw and label some of the geometric shapes on the board (e.g., trapezoid, hexagon, diamond).

Do not hesitate to answer questions about the animals pictured on the cards. The lesson concerns the concept of grouping. The same cards will be used again in the next investigation. The more familiar the students are with the animals, the more successful they will be in seeing the concept.

Have the students take an inventory count of the cutouts and picture cards before collecting them.

Discussion and Review: Investigations 6 and 7 are closely related. After the students conclude that living things can be arranged into related groups, ask them, "How?" or "What is the best method?" Don't answer the question. Provide enough curiosity to serve as a transition into Investigation 7.

ENRICHMENT

1. Use the Elementary Science Study (ESS) unit, *Attribute Games and Problems,* in which students explore the problem of classification and become skillful in dealing with the relationships between classes.

REFERENCES

Books and Articles

Buffaloe, Neal D., *Animal and Plant Diversity.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968.

Savory, Theodore, *Naming the Living World.* New York: John Wiley and Sons, 1963.

Multi-Media Aids

Attribute Games and Problems: Webster Division, McGraw-Hill Book Co., 1968.

Animal Life: Printed originals or transparencies, color, 23 visuals, 3M Company 15-0790.

Animal Structure–Part I: Printed originals or transparencies, color, 20 visuals, 3M Company 15-3612.

Animal Structure–Part II: Printed originals or transparencies, color, 20 visuals, 3M Company 15-3613.

Sea Shell Animals: 16 mm, color, 11 min., Bailey-Film Associates 16-7N.

Wild Animal Families: 16 mm, color, 11 min., Bailey-Film Associates 16-17N.

How Living Things Move: 8 mm film loops, color, 6 single concept loops, Warren Schloat Productions 177.

POSSIBLE ANSWERS

TABLE NO. 1
SEPARATION OF CARDS INTO RELATED GROUPS

Cards can be grouped according to:	Kinds of cards in each group
Colors	Black, red
Suits	Spades, clubs, hearts, diamonds
Numbers	A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K
Face and Numbers	J, Q, K and A, 2, 3, 4, 5, 6, 7, 8, 9, 10

1. Grouped according to suit, color, and number.

TABLE NO. **2**

SEPARATION OF CUTOUTS INTO RELATED GROUPS

Cutouts can be grouped according to:	Kinds of cutouts in each group
Color	Red, blue, green, yellow
Size	Small, medium, large or 1½", 2", 2½", 3"
Shape	Triangle, trapezoid, circle, square, rectangle, diamond, star, hexagon
Sides	0 or 1, 3, 4, 6, 10

2. Grouped according to color, size, shape, corners, and sides.

TABLE NO. **3**

SEPARATION OF ANIMALS INTO RELATED GROUPS

Animals can be grouped according to:	Characteristics in each group
Covering	Feathers, hair, scales, skin
Locomotion	Swim, fly, run, crawl
Heart, chambers	2, 3, 4
Appendages	Fins, wings, arms, legs
Respiratory mechanism	Gills, lungs

3. Grouped according to covering, locomotion, number of heart chambers, appendages, and respiratory mechanism.
4. Arranged into related groups.

CONCEPT SUMMARY: Living things can be arranged into related groups.

CLASSIFICATION

Classification is an academic card game designed for use in the *Ideas and Investigations in Science* (IIS) program, but can be used in any program where the teacher wants to teach the concept of classification. Through the use of pictured playing cards, the student learns how to order and group objects.

You will need one deck for every group of four students. There are 64 cards in each deck comprised of the following.

Quantity	*Cards*	*Class**
4 each (total 12)	Salmon, betta, perch	Fish
4 each (total 12)	Frog, toad, salamander	Amphibian
4 each (total 12)	Alligator, lizard, turtle	Reptile
4 each (total 12)	Duck, canary, hawk	Bird
4 each (total 12)	Deer, man, seal	Mammal
4 each	Wild	

*Note that the cards are not labeled with the class into which each animal falls. The player learns how to classify by reading and comparing the appropriate traits printed on each card.

You will need the cards for Biology: Idea 2, Investigations 6 and 7. Give each student or team of students one set. The use of these cards is explained in the text of the investigations. Do not use the wild cards.

After the students complete each investigation, they can use the cards to play *Classification, Relatives,* and *Family,* explained below:

CLASSIFICATION (for 2 to 4 players per deck)

To Start: Shuffle well and deal seven cards to each player. Place the remaining deck face-down as a drawing pile and turn over one card to start the discard pile. If a wild card shows, turn over another.

To Play: The play starts on the dealer's left and goes clockwise. Each player may pick up the top card from either the drawing pile or the discard pile. Play continues, in turn, after each player discards a card. Each player must discard a card, except when he declares himself a winner by saying, "Classification!"

To Win: The winner is the first person to lay down 8 cards in the following pattern:

3 different cards from one *class*-ification (e.g., salmon, betta, perch)

3 different cards from *another class*-ification (e.g., alligator, lizard, turtle)

2 different cards from *another class*-ification (e.g., man, deer)

This game may be played with or without the wild cards.

To Renew: If the drawing pile runs out, keep the last discard face-up. Shuffle the others and place face-down.

To Vary: Two suggested variations, although of lesser learning value, include:

a. 3 identical cards from one classification
   3 identical cards from another classification
   2 identical cards from another classification

b. 3 identical cards from one classification
   3 identical cards from the same classification
   2 identical cards from the same classification

RELATIVES (for 4 or more players)

To Start: Use one deck of cards for five players. If four play, remove the 12 cards belonging to one classification (e.g., all fish cards). If more than five play, add 12 cards from one classification from another deck. You can play with or without the wild cards.

Deal an equal number of cards to each player. Each player will have 12 cards, or 13 if the wild card is used.

To Play: One card at a time is passed, face down, to the person to the left every time the dealer calls "Pass." This procedure continues until someone calls, "Relatives," and is declared the winner.

To Win: The winner is the first person to acquire all 12 cards (or cards plus wild cards) belonging to the same classification. If the wild cards are used, each player should remember that he will always have one extra card.

To Vary: Award 100 points to the winner of each game, with 500 points the ultimate winner.

Play with two wild cards. Declare one wild card the "Outcast." If a player has this card when the game ends, subtract 50 points. Declare the other card the "Double Jeopardy." If a player has this card when the game ends and is the winner, award an extra 100 points, but subtract 50 points if not the winner.

FAMILY (for 4 or more players)

To Start: Proceed as in *Relatives.*

To Play: When the dealer has determined that every player has had enough time to organize his cards, he calls, "Trade." Every player is on his own and lays down any number of related cards he wants to trade. For instance, he can call, "Trade, three–," and place down two salmon cards and one perch card. You cannot trade unrelated cards (e.g., two bird cards and one mammal card).

Trade is consummated when another player is found who wants to trade an equal number of cards (all related). You can change the number you want to trade to match someone else's number. Continue to trade, fast and furious, getting rid of the cards you do not want for the cards you want until someone yells, "Family" and is declared the winner.

To Win: The winner is the first person to acquire all 12 cards (or cards plus wild cards) belonging to the same classification. If the wild cards are used, each player should remember that he will always have one extra card.

To Vary: Use the same variations suggested in *Relatives.*

BIOLOGY IDEA 2: EVOLUTION, Investigation 7 (2-5 periods)

PURPOSE: Develop the concept that living things can be arranged into related groups based on their structure.

DEVELOPMENT: The student will feed data into a set of punch cards and then sort them into related groups. The student will see that the sorting system is built on structural similarities.

HIGHLIGHT: By the time the students sort out the animals with the characteristics mentioned in question 16, the notion of grouping organisms according to structure should be meaningful.

MATERIALS (for each team of two)

Deck of animal picture cards from the game, *Classification,* used in Investigation 6

Data punch cards, 15[1]

Length of clothes-hanger wire or straightened paper clip

Preparation of Materials

1. If you do not have an IIS equipment package, you can prepare your own data punch cards on index or data processing cards. The latter can be purchased from companies such as IBM for about 89¢ per thousand. They come in a variety of colors, with square or rounded corners, and with a cut at the right- or left-upper corner. They can be run through a spirit duplicator or mimeograph machine.

TEACHING TIPS

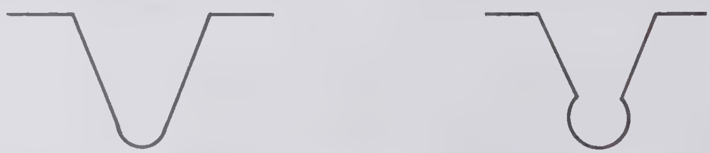
Responses to Expect: Students will be confused when sorting the cards unless you show them that they should sort the cards that fall out of the deck and continue doing so.

Expect additional questions to arise concerning the animals themselves. Answer them directly or have resource materials available.

Practical Hints: Slower students probably view the different life forms as separate entities. The purpose of this lesson is to help them see relationships.

Review the different ways the playing cards, cutouts, and animal cards were sorted in the last investigation. Discuss the relative merits of the sorting systems. For instance, a classification system based on locomotion (those that swim, fly, run, crawl) is better than one based on feathers (those with and those without).

It is highly recommended that you lead the entire class in the preparation of one of the data punch cards. The scissor cuts must form the shape of a narrow "V." A correct and incorrect cut are pictured below.



Correct Incorrect

The class should check the information transferred to the data punch cards before the actual sorting starts. If the data are punched incorrectly, the system will not work.

Discussion and Review: Indicate that the data punch cards represent a crude mechanical computer system. As with any computer, the answers will only be as correct as the data fed into the system.

Pose the question to the class, "How are mammals different from birds, or reptiles from amphibians?" Let them decide that classification is made on the basis of body structure.

ENRICHMENT

1. Have the students design a key or data punch card system of their own.
2. Have students write a paper on Linnaeus.
3. Prepare a chart showing the different groups of organisms and the basis for the grouping.

REFERENCES

Books and Articles

Beebe, W., "What's in a Butterfly's Name." *Animal Kingdom,* 1948, pp. 14-15.

Solbriq, Otto T., *Evolution and Systematics.* New York: The Macmillan Co., 1966.

Wood, Robert W., *How to Tell the Birds from the Flowers.* New York: Dover Publications, Inc., 1959.

Multi-Media Aids

Classification and Natural History: Filmstrip set, color, 6 filmstrips, 50 frames each, Ward's 70 W 3200.

Animal Classification: Lesson Pak, Ward's 36 W 1300.

World of One-Celled Animals: Filmstrip, color, 40 frames, Popular Science 590.

Roll Call of the Animals: Filmstrip, color, 40 frames, Popular Science 563.

Roll Call of the Plants: Filmstrip, color, 40 frames, Popular Science 573.

The Fungi–Non-Green Plants: Filmstrip, color, 40 frames, Popular Science 1504.

Methods of Identifying Trees: Filmstrip, color, 40 frames, Popular Science 1526.

POSSIBLE ANSWERS

1. No, because many animals live in more than one place.
2. No, because many animals have different patterns. (There may also be variation within the species and between the sexes.)
3. They are classified by how they look, by their body structure, and by what they eat.
4. Salmon, betta, perch.
5. They all have the characteristics of fins, scales, 2-chambered heart, gills, and teeth along the jaw. They all have the same general body structures.
6. Fish.
7. Frog, toad, salamander.
8. They all have the same characteristics.
9. Amphibians.
10. Alligator, lizard, turtle.
11. The grouping is based on body structure.
12. Reptiles.
13. Duck, canary, hawk.
14. The classification system is based on body structure.
15. Birds.
16. Deer, man, seal.
17. The animals are being classified on the basis of body structure.
18. Mammals.
19. Linnaeus arranged living things into groups based on their structure.
20. Structure.
21. Structure.

CONCEPT SUMMARY: Living things can be classified into related groups based on their body structure.

BIOLOGY IDEA 2: EVOLUTION, Investigation 8 (2-4 periods)

PURPOSE: Develop the concept that fossils furnish evidence that living things have existed through time.

DEVELOPMENT: The students will make model fossil castings and examine fossil specimens. They will infer that fossils represent organisms or parts of an organism that have been preserved through time.

HIGHLIGHT: The two activities in part B enable the student to simulate ways in which fossils have been preserved.

LOOK AHEAD: If you do not have an IIS Color Kit and Size Kit, prepare the different colored squares which will be used in Investigation 11.

MATERIALS (for each team of two)

- Play-Doh, 4" x 2" x 1½"
- Soap solution in dish (Optional)
- Pencil or ¼" dowel
- Aluminum foil

MATERIALS (for entire class)

- Basic fossil kit
- Paraffin (Melt just before use)
- Petrified wood samples (Optional)

TEACHING TIPS

Responses to Expect: Students often have the preconceived notion that all fossils are rocks. They may also think that fossils are only a few thousand years old. Be prepared to correct these mistaken ideas.

Practical Hints: This investigation provides a transition to the next five investigations. These latter investigations all have the theme of evolutionary change. To establish the fact that change has taken place, the student will infer that life existed in the distant past and some of this life has been preserved as fossils.

The introductory paragraphs in part A are an important adjunct to question 1. Discuss the dinosaurs and giraffes (and any other organisms) to hint that change may have taken place. However, never mention the word "change." Provide the student with some background so that he can make a reasonable prediction in question 1. If this is not done, students will make such predictions as, "They have been living, dying, or growing larger."

Stress the importance of the answer to question 2. It is one thing to make a prediction, and another to find evidence to support or reject the prediction. The students may want to change their prediction if they see that they cannot supply possible evidence.

In part B, the students discover two ways in which organisms have been preserved. These simple activities should increase student understanding of fossils.

There are 20 fossil models in an IIS equipment package. This should be sufficient for a class. The liquid soap used in dispensers at schools for washing hands will suffice. If you use concentrated dishwashing soap, dilute it at least 5 to 1.

To prevent accidental burns, you and/or a teacher aide should pour the melted wax into the Play-Doh blocks. The melted wax is reusable and hardens in 15-20 minutes. You may speed up the process by placing the setups in a refrigerator. (Plaster of Paris may be substituted for the melted wax.)

Discussion and Review: Student answers to the questions in part C will indicate whether the students truly understand the significance of fossils.

ENRICHMENT

1. Have students examine and write a paper on the nature of petrified wood or fossiliferous limestone.
2. Prepare a chart that shows how fossils can be used to determine the age of geological strata.
3. Have students prepare a paper or chart on dinosaurs.

REFERENCES

Books and Articles

Fenton, Carroll L. and Mildred A., *The Fossil Book.* Garden City, N.Y.: Doubleday & Co., Inc., 1959.

Goldring, W., *Handbook of Paleontology for Beginners and Amateurs: Part 1, The Fossils.* Ward's Natural Science Establishment.

Matthews, William H., *Fossils: An Introduction to Prehistoric Life.* New York: Barnes and Noble, 1962.

Multi-Media Aids

Dinosaurs: Giant Reptiles of the Past: Filmstrip, color, 40 frames, Popular Science 606.

The Story of Fossils: Filmstrip, color, 40 frames, Popular Science 569.

An Introduction to Fossils: Filmstrip set, color, 6 filmstrips, 320 frames, Ward's 71 W 2300.

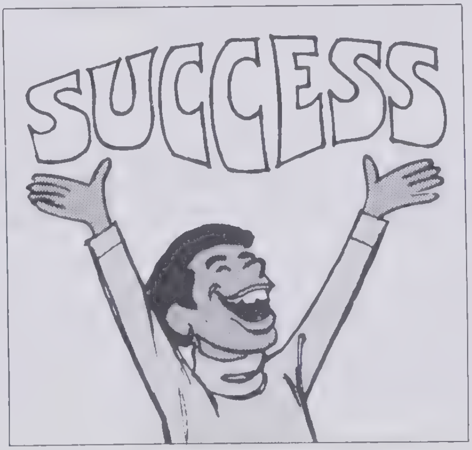
Find-A-Fossil: Lesson Pak, Ward's 36 W 1840.

Fossil Collections and Specimens: Ward's.

POSSIBLE ANSWERS

1. They have been changing.
2. Fossils. *Or,* remains of prehistoric living things from a succession of time periods.
3. A fossil.
4. A fossil. *Or,* the cast represents a model of the original organism.
5. A fossil.
6. It tells us how prehistoric living things might have looked, and if they have changed.
7. Fossils. *Or,* remains of prehistoric living things from a succession of time periods.

CONCEPT SUMMARY: Fossils furnish evidence that there were living things in prehistoric days. (The student can only assume that change has occurred. This will be clarified in the next investigation.)



BIOLOGY IDEA 2: EVOLUTION, Investigation 9 (2 periods)

PURPOSE: Develop the concept that fossils are one form of evidence that living things have changed through time.

DEVELOPMENT: The students will examine data from fossil horse teeth and legs and make a graphical comparison.

The students will infer from the graphical comparison that living things have changed through time.

HIGHLIGHT: By graphing the information concerning changes in the span of cheek teeth (in the horse), the students should obtain a clear picture of change and a growing curiosity about why the changes occurred (part A).

LOOK AHEAD: Pea seeds used in Investigation 10 must be presoaked for 12-24 hours.

MATERIALS: None

TEACHING TIPS

Responses to Expect: It may be necessary to review graph making, studied in Biology Idea 1: *Inquiry.*

The students may tend to overemphasize the names of the horses. The unfamiliar names are secondary.

Practical Hints: Part A is not an exercise on how to graph. Some of the students may need special assistance in beginning the graph.

Be sure the students understand the relationship between the span of teeth, and the period of time in which the prehistoric horses lived.

Wax mold sets of fossil horse teeth can be purchased from Macalaster Scientific Co. Use these to supplement the discussion on the span of horses' teeth.

Discussion and Review: When discussing the investigation, do not be concerned with correct answers to questions 2 and 6. Get the students to make possible explanations. List them. Their explanations will serve as a transition to Investigation 11 in which natural selection is discussed.

Draw attention to questions 1 and 5. If the students can answer "change," then they may be able to see the larger concept which is brought out by question 7.

ENRICHMENT

1. If you purchase a set of fossil horse teeth models, have the students measure the size of similar teeth and suggest explanations for the change.
2. Prepare a drawing on the evolution of the horse.

REFERENCES

Books and Articles

deBeer, Sir Gavin, *Atlas of Evolution.* Camden, N.J.: Thomas Nelson & Sons, 1965.

Ross, Herbert H., *Understanding Evolution.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1966.

Multi-Media Aids

Prehistoric Life: Filmstrip series, color, 6 filmstrips, 55 frames each, Encyclopaedia Britannica 7500.

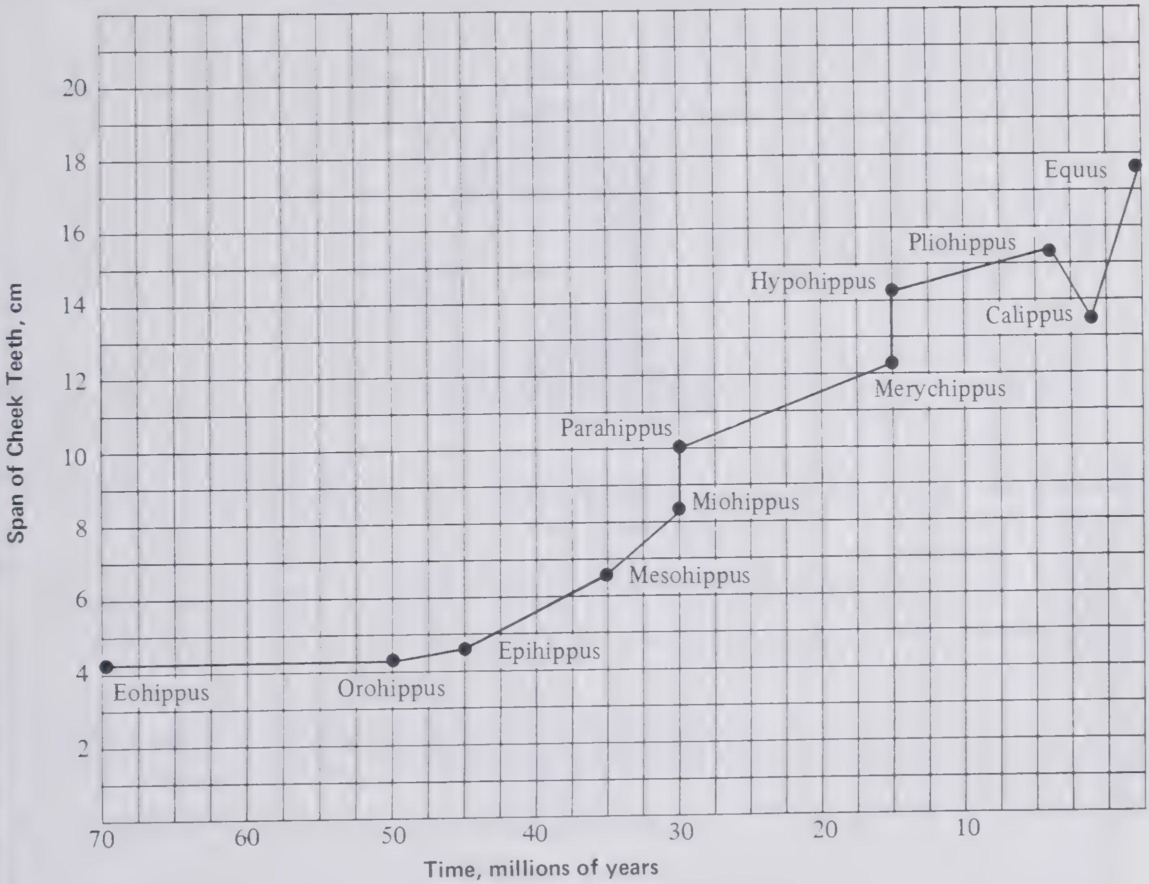
Learning About Dinosaurs: 17" x 11" prints, color, 10 prints, Encyclopaedia Britannica 5980.

Fossils: Sound filmstrip series, color, 5 filmstrips, 47 frames each, Encyclopaedia Britannica 6413.

POSSIBLE ANSWERS

GRAPH NO. 1

THE SPAN OF CHEEK TEETH IN VARIOUS HORSES THROUGH HISTORY



1. They have been changing. They have increased in size.

2. The horses grew larger. The diet changed. The horses with the larger teeth were able to survive better. (Correct answer is immaterial. Motivate student to think about possible explanations.)

3. Eohippus with four toes in front and three in the back (visible from the drawings).

4. The modern horse has one toe, commonly called a hoof. (The modern horse actually runs on its toenail.)

5. They have been changing. The number of toes decreased through time, but the resulting toe or hoof increased in size.

6. They could run better. They could stand better. Those horses with larger toes could run better. Those who could run faster escaped their enemies. (The correct answer is immaterial. Get the student to think about possible explanations. He will find the answer in Investigation 11.)

7. Living things have been changing through time.

CONCEPT SUMMARY: Fossils furnish evidence that living things have changed their structure through time.

When the students draw their graphs, be sure the quantity appears on the vertical axis. Otherwise, the students will not see the characteristic "bell-shaped" curve.

PURPOSE: Develop the concept that there is variation within a species.

DEVELOPMENT: The student will measure pea seed diameters, leaf length, human reaction distance, and the random fall of balls in a probability device.

The student will plot each set of data on a separate graph and note the normal distribution curve in each graph. This will indicate a definite pattern to variation within a species.

HIGHLIGHT: By graphing the results of each activity, the students will have a vivid illustration of the pattern that exists in variety.

LOOK AHEAD: If you do not have an IIS Color Kit and Size Kit, prepare materials needed in Investigation 11.

MATERIALS (for each team of two)

- Pea seeds, soaked 12-24 hours, 10 to 15
- Small branch with at least 10 leaves on it
- Ruler, metric and English
- Petri dish
- Probability device

TEACHING TIPS

Responses to Expect: The students may claim that they need a razor blade to split the peas. If you have soaked the peas overnight, fingernails will be adequate for the task.

The students will enjoy working with the probability device. Be sure that the data needed for this investigation are all collected in a uniform, controlled manner.

The four graphs will not all look exactly alike. Use of "best-fit" curves will make the somewhat abstract concept more visible to the students.

Practical Hints: It is highly recommended that each of the four activities be done separately. In other words, you should:

a. Explain and demonstrate what has to be done.

b. Let the students complete their task.

c. Place a copy of the class data table on the blackboard or on a transparency.

d. Have one student from each team add his team's count to the class data table.

e. Clean up the materials before drawing the graph.

f. Allow the students time to draw the graph before proceeding to the next part.

(Although four activities are provided, you may find that only three are sufficient for your group. Pilot groups have found the repetition helpful.)

All of the peas should be split first. Use plastic Petri dishes to hold one-half of each pea. Have the students discard all the peas in one dish immediately. This will prevent any accidental, duplicate measuring of a pea. (If the peas are not perfectly round, measure the largest diameter.)

There is no need to start the data table at 0 mm. The table only need cover the range of actual pea sizes. Determine the approximate range of pea sizes based on student measurements. Then have the students use this range in their graphs.

Discard the peas immediately after the students finish measuring. You may, if you wish, save the pea halves for the next class to measure.

In obtaining leaves, do not collect single leaves off a plant. Take the entire ends of branches. There is a greater probability of obtaining normal distribution curves if you use this method.

Have the students strip all the leaves off the branch. You can disregard the very tiny terminal leaves. Discard these leaves and the branch before measuring.

The greatest range in size will come from the leaves. To keep the table down to a reasonable size, tally the counts into groups of fives or tens. Generally, groups of ten give a more normal distribution.

When doing the reaction distance activity, be sure the subject's arm is on a table, otherwise he may move his hand downward with the fall of the ruler.

Although the reaction distance table indicates measurement in inches, you can use the metric side of the ruler instead. If you use the metric system, however, note that the length of the data table will increase nearly threefold. Also, the increase in numbers will spread out the data and there will not be as symmetrical a normal distribution curve.

When using the probability device, students must flip the apparatus over and allow the balls to fall perpendicular to the floor. If the students want to experiment with the device and see what happens when the balls are allowed to drop at an angle, let them, but *after* the data required for this investigation are obtained.

Investigations 10-12 are a unified block. Try not to allow disruptions to interfere with the continuity of concepts. In this investigation, the basic concept necessary for an understanding of Darwinian theory is developed. Be sure that the students understand that although there is variation within a species, there is a pattern to the variation.

In the next investigation, the students will see how natural selection occurs in a normal distribution curve. In the last investigation, the theory of natural selection will be applied to a specific subject, skin coloration.

Discussion and Review: Review the nine concepts learned to date. The next three investigations bring this Idea to a climax. For this reason, it is imperative that the students see the continuity of concepts learned thus far.

The set of questions in part E can very profitably be used for discussion. Be prepared for student reaction to the social implication of questions 12-15.

REFERENCES

Books and Articles

Buffaloe, Neal D., *Animal and Plant Diversity.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968.

Hanson, Earl D., *Animal Diversity,* 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Simpson, George G., *The Meaning of Evolution.* Rev. Ed. New Haven: Yale University Press, 1967.

Multi-Media Aids

Introduction to Probability: Printed originals or transparencies, color, 23 visuals, 3M Company 15-0745.

POSSIBLE ANSWERS

TABLE NO. 1
COMPARISON OF PEA SIZES, mm

Diameter of Peas, mm	3	4	5	6	7	8	9	10	11	12
Personal Count										
Total Class Count	1	9	19	34	42	36	17	6	2	0

GRAPH NO. 1
TOTAL CLASS COUNT OF PEA DIAMETERS, mm

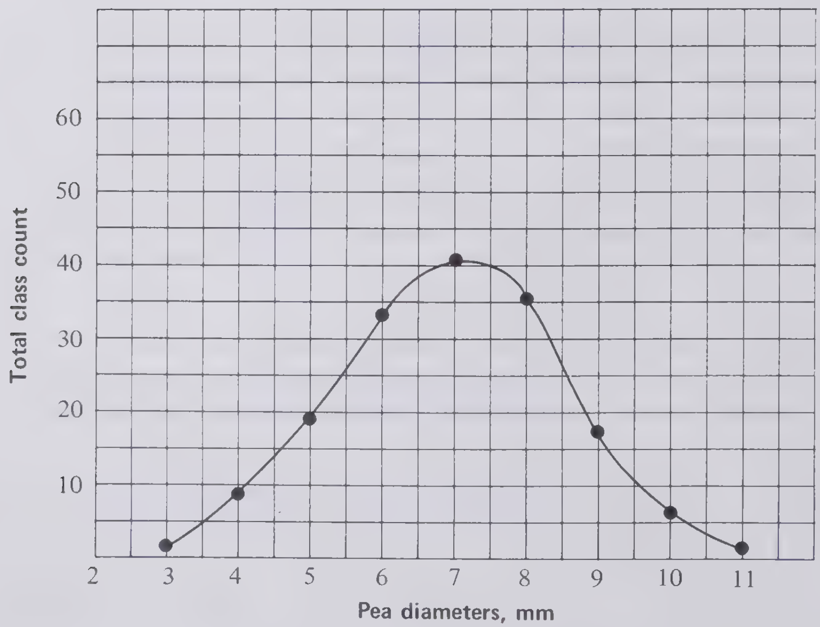


TABLE NO. **2**

COMPARISON OF LEAF LENGTHS, mm

Length of Leaves, mm	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85								
Personal Count	~~IIII~~ II	III	I	I	IIII	I	II	III	III	III	II		II	IIII	IIII	IIII	I								
Total Class Count	11	8	19	31	51	72	90	108	111	102	101	90	68	53	22	8	1								

GRAPH NO. **2**

TOTAL CLASS COUNT OF LEAF LENGTHS, mm

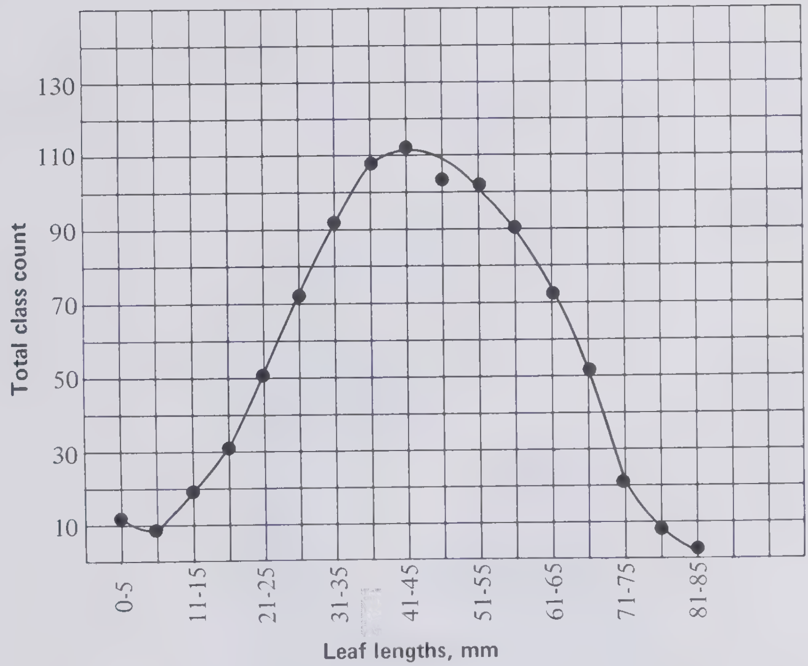


TABLE NO. **3**

COMPARISON OF STUDENT REACTION DISTANCE, INCHES

Reaction Distance, Inches	1	2	3	4	5	6	7	8	9	10	11	12
Personal Reaction Count				I	II	III	IIII					
Total Class Count	1		9	34	51	70	55	20		5	1	

GRAPH NO. **3**
TOTAL CLASS COUNT OF
STUDENT REACTION DISTANCES

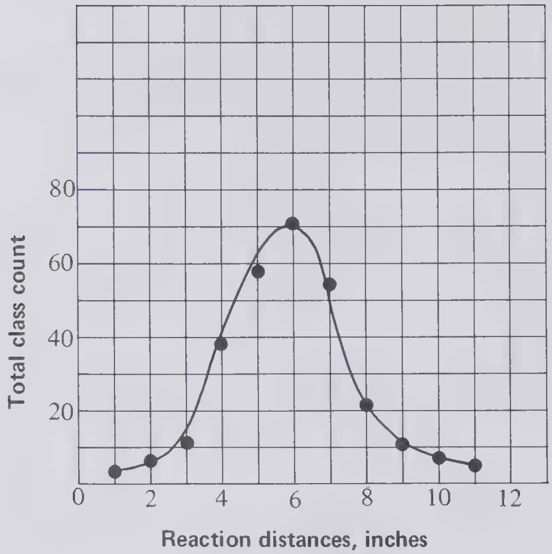
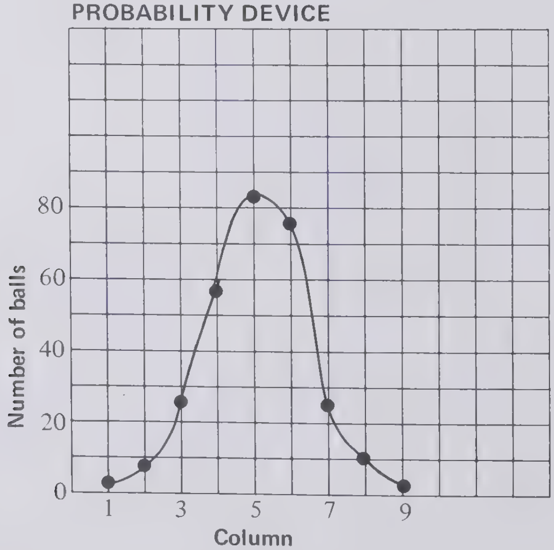


TABLE NO. **4**
DISTRIBUTION OF BALLS IN A PROBABILITY DEVICE

Column	1	2	3	4	5	6	7	8	9
Number of Balls	1	5	25	55	72	58	26	10	3

GRAPH NO. **4**
DISTRIBUTION OF BALLS IN A
PROBABILITY DEVICE



1. They all have the same shape.
2. A bell, mountain, or upside-down U.
3. No. There would be a straight vertical line if all were the same.
4. They are all different, but most are average with a gradual tapering off at both extremes.
5. They are all different, but most are average.
6. They are all different, but most are average.
7. The same as peas, leaves, reaction distance, or bell-shaped graph.
8. Bell-shaped.
9. Bell-shaped.
10. Bell-shaped.
11. No. All individuals are different, but most are average. There are fewer individuals as you progress farther from the average.
12. They are all different, but most are average.
13. They are all different, but most are average.
14. They are all different, but most are average.
15. They are all different, but all are people.
16. They are all different, but most individuals are average.

CONCEPT SUMMARY: Individuals differ, but most are average. *Or,* there is variation within a species.

Put the contents of the first envelope in the box before class.

PURPOSE: Develop the concept that nature selects the fittest to survive.

DEVELOPMENT: The students will pick out different-colored and different-sized objects and note that their selections are not a normally distributive selection.

They will apply this knowledge toward an understanding of Darwin's Theory of Natural Selection, and an explanation of how certain animals have evolved through history.

HIGHLIGHTS: The students will get a concrete example of natural selection when they select the different-colored and different-sized objects from a black box. Part C provides a basic understanding of evolution in simple yet imaginative terms.

MATERIALS (for each team of two)

- IIS Color Kit, Hickok Teaching Systems or prepare your own[1]
- IIS Size Kit, Hickok Teaching Systems or prepare your own[2]
- Container, two, jar or envelope
- Shoebox (spray the inside black, or line the inside with black construction paper)

Preparation of Materials

1. An IIS Color Kit consists of 114 squares, in nine colors ranging from black to white. You can prepare your own kit using stiff cardboard. The squares should be 1" x 1". The number of squares of each color are as follows:

	Black →				Gray →				White
Color No.	1	2	3	4	5	6	7	8	9
Quantity	6	9	12	18	24	18	12	9	6

After the paint dries, mix and package all 114 squares in a container.

2. An IIS Size Kit consists of 114 black paper squares of the following sizes:

Size, in. x in.	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
Quantity	6	9	12	18	24	18	12	9	6

Mix and package all 114 squares in a container.

TEACHING TIPS

Responses to Expect: Students will want to open the shoebox to see what is inside. Try to complete the activity as quickly as possible to prevent the students from analyzing what they are supposed to do.

You may have some students who do not believe in evolution. Their beliefs should be respected. Evolution is a theory, not a fact. Encourage your students to base their conclusions on the evidence available.

Practical Hints: Use the introductory paragraphs and illustrations to review the past lesson.

You may have to define some terms such as extinct, predator, generation, survivor, and industrialized.

Have a class data table on the blackboard or on a transparency ready to receive each team's data.

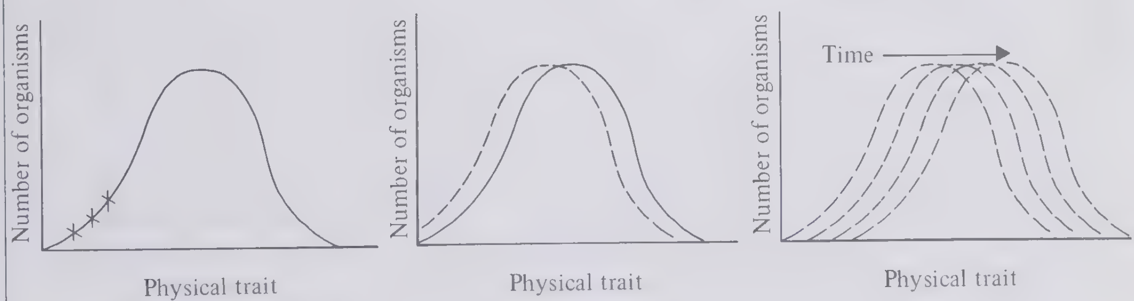
Complete both activities, including the tabulation of the class data, before you discuss the investigation with the class.

Discussion and Review: It is highly recommended that you discuss each section separately and in sequence, since the concept of natural selection is difficult to understand.

In your discussion, tie the concept of variation (Investigation 10) to the concept learned in this investigation. Show the relationship and significance of the number of squares to the normal distribution curve discovered previously. That is, variation within a species is normally distributive.

Point out that nature does not necessarily select from the most popular trait in a population. Selection frequently is at either end of the curve.

If the experiment is done properly, the students will see that the entire curve should shift with each succeeding generation. There will always be variation within a species, but the mean of the variation will shift as is illustrated below.



X = unfavorable organisms which will die

---previous generation
—next generation
(variation within the species again, but the mean has shifted)

ENRICHMENT

1. Draw a map of Darwin's travel on the *Beagle*.
2. Prepare a chart describing the flora and fauna of the Galapagos Islands.

REFERENCES

Books and Articles

Cooper, George Allen, *Charles Darwin.* New York: The Macmillan Co., 1966.

Darwin, Charles, *The Origin of Species.* New York: New American Library.

Darwin, Charles, *The Voyage of the Beagle.* New York: Harper & Row, 1959. (Edited by Millicent E. Selsam for grades 7-11.)

Himmelfarb, Gertrude, *Darwin and the Darwinian Revolution.* Garden City, N.Y.: Doubleday & Co., Inc. (Anchor Books), 1962.

Stebbins, G. Ledyard, *Processes of Organic Evolution.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1966.

Wallace, Bruce, and Adrian M. Srb, *Adaptation.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Multi-Media Aids

Darwin's Finches: Clues to the Origin of Species: 16 mm, color, 10.5 min., Bailey-Film Associates 16-63.

Birds: How They Live, Where They Live: 16 mm, color, 11 min., Bailey-Film Associates 16-189.

Animal Camouflage: Insects: 8 mm film loop, color, Ealing 81-3360/1.

Escape in Mammals: 8 mm film loop, color, Ealing 81-3071/1.

The Seashore–Plant and Animal Adaptations: 8 mm film loop, color, Encyclopaedia Britannica 80723.

Desert in Daylight: 8 mm film loop, color, Encyclopaedia Britannica 80862.

Living Things Through the Ages: Filmstrip series, color, 4 filmstrips, 48 frames each, Encyclopaedia Britannica 11160.

POSSIBLE ANSWERS

TABLE NO. 1
DISTRIBUTION OF DIFFERENT COLORED OBJECTS

Colored Objects Selected	Black 1	2	3	4	5	6	7	8	White 9
Personal Count					|	|	||	|	
Total Class Count		2	6	12	18	15	10	8	4

1. Bell-shaped.
2. The individuals differ, but most are average.
3. More light objects.
4. It was easier to see and pick up the lighter squares on the black background.
5. Bell-shaped.
6. The individuals differ, but most are average.
7. More large objects.
8. All the squares were the same color as the background. Therefore, it was easier to see and pick up the larger ones.
9. There was a normal distribution of moths, but most were medium in color.

10. The darker moths, because they were easier to see against a lighter background.
11. Light-colored moths.
12. They became darker and darker from the smoke deposits.

TABLE NO. 2
DISTRIBUTION OF DIFFERENT SIZED OBJECTS

Size of Objects Selected	Small 0.5"	1.0"	1.5"	2.0"	2.5"	3.0"	3.5"	4.0"	Large 4.5"
Personal Count									
Total Class Count		1	5	10	19	16	12	7	5

13. The lighter moths. They were easier to see against the dark tree trunks.
14. Dark-colored moths.
15. The moths would become mostly dark in color.
16. Change in the environment.
17. The slower ones.
18. The faster ones.
19. Longer legs and larger center toe. They ran faster.
20. Offspring with longer legs and a larger center toe (hoof).
21. The horse with the longer leg and larger center toe ran faster, survived, and reproduced more of his own kind.
22. The ones with small teeth (to cut and graze).
23. The ones with large teeth (to chew).
24. Larger, stubbier teeth for grinding.
25. Offspring with larger and stubbier teeth.
26. It is easier to chew tough grasses with large teeth. Horses with this characteristic survived to reproduce more of their own kind.
27. The differences that are more favorable for the environmental condition.
28. The individuals with better features; the fittest ones; the more favorable ones.
29. Nature selected the longer necked giraffes to survive. They reproduced more of their own kind each generation. Over a period of time, giraffe necks got longer and longer.
30. As groups of organisms were separated or migrated away from the main group, changes due to natural selection took place in their new environments. Each change distinguished the separated group from the main group until a new species evolved.
31. The fittest.

CONCEPT SUMMARY: Nature selected the fittest to survive.

BIOLOGY IDEA 2: EVOLUTION, Investigation 12 (2-3 periods)

PURPOSE: Develop the concept that skin coloration is the result of natural selection.

DEVELOPMENT: The students will learn that there is a delicate balance between the amount of melanin and vitamin D produced by the skin.

The students will use this knowledge to conclude that skin coloration is an evolutionary result, necessary to regulate the amount of vitamin D produced by the skin.

HIGHLIGHT: The highlight of this investigation is the student application of evolution to a relevant concern—the races of man.

LOOK AHEAD: Prepare the necessary materials for Idea 3 (Genetics), Investigations 1 to 3.

MATERIALS: None

TEACHING TIPS

Responses to Expect: Considering the relevance of the topic, the best way to open this lesson is to pose the question, "How did skin coloration originate?" Students will differ in their opinions. Point out that the version given in this investigation represents only one explanation, but there are data to support the theory. Does the student have data to support his version?

Practical Hints: Review Investigations 10 and 11, since an understanding of natural selection is basic to this investigation.

There are two very obvious messages in this investigation. The first is that there is no scientific basis for racial prejudice. Skin coloration is a favorable trait preserved to assist the survival of people living in a particular environment.

The other message is that evolution is a concept that can be applied to many situations other than science. History evolves. Jobs evolve. So do football techniques. Stress that the student is going to have to adapt to a very rapidly changing world.

Discussion and Review: Conclude this investigation by discussing the concept of skin coloration (questions 10-13). Then review the entire Idea.

ENRICHMENT

1. Compare a scientist's and an anthropologist's interpretation of the concept of race.
2. Prepare a paper or display on the races of man.

REFERENCES

Books and Articles

Ehrlich, Paul R., and Richard W. Holm, *The Process of Evolution.* New York: McGraw-Hill Book Co., 1967.

Nogar, Raymond J., *The Wisdom of Evolution.* Garden City, N.Y.: Doubleday & Co., Inc., 1963.

Washburn, S.L., "The Study of Race," *American Anthropologist,* June, 1963, Vol. 65, No. 3.

Multi-Media Aids

Evolution of Man: 16 mm, color, 13.5 min., Coronet 1721.

Man from the Dim Past: Filmstrip, color, 40 frames, Popular Science 581.

The Evolution of Man: Filmstrip set, color, 6 filmstrips, 281 frames, Ward's 70 W 3500.

The Dawn of Life: 16 mm, color, 28 min., Aetna Life Insurance Co.

POSSIBLE ANSWERS

1. If the sun is intense and there is a lack of melanin.
2. Dark.
3. The melanin blocks out much of the sun, thus keeping the production of vitamin D to a minimum.
4. Their skin cells would produce an excess of vitamin D.
5. It became a darker color.
6. Light.
7. The absence of much melanin allows ultraviolet light to penetrate and cause the skin to produce vitamin D.
8. The melanin would prevent the ultraviolet light from reaching the vitamin D-producing cells.
9. It became a lighter color.
10. Dark-colored skin is best where the sun's rays are very intense. Light-colored skin is best where the sun's rays are less intense.
11. The melanin in dark-colored skin blocks out much of the sun, protecting a person from producing too much vitamin D.
12. This allows more sun through to make the right amount of vitamin D.
13. People with light-colored skin are usually farthest from the Equator, where the sun is not very strong. Light-colored skin allows the maximum amount of light which is necessary to make vitamin D.

CONCEPT SUMMARY: Skin coloration is the result of natural selection.

IDEA SUMMARY: Living things have been changing through time, thus giving rise to a diversity of life.

Idea 3
Genetics

Each Idea in the IIS program is a self-contained unit and is not dependent upon another Idea as a prerequisite. However, if your students are not familiar with the inquiry processes of science, it is highly recommended that the program begin with Biology Idea 1. After Idea 1 you can follow with any Idea in any order you choose, from Biology or Physical Science.

If you have now chosen Idea 3, your students will discover, when they finish, the IDEA Summary that:

ALL LIVING THINGS HAVE PASSED ON TRAITS FROM GENERATION TO GENERATION WITH A CONTINUITY OF PATTERN.

The IDEA Summary is developed from a sequence of twelve concepts. These concepts are listed in the chart on the next page. Notice that the Idea is divided into two main parts. The first four investigations are concerned with reproduction and the last investigations are concerned with the mechanics of inheritance.

A major feature of IIS is its concern with scientific subjects that are socially relevant. These are the topics that interest and directly affect the students. The most prominent socially relevant topics in Idea 3 are in Investigations 2 and 4A, which consider the population problem and venereal diseases, respectively.

Remember, the purpose of IIS is not to train future scientists or technicians. Rather, we hope that IIS will help produce citizens who are aware of scientific problems with social implications.

BIOLOGY: IDEA THREE (GENETICS)

All Living Things Have Passed on Traits from Generation to Generation with a Continuity of Pattern

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. AND THE BEAT GOES ON	Life comes from previous life.	Pasteur swan-neck experiment
2. DON'T CROWD ME, BABY	A population can multiply very rapidly.	Bacterial growth; population control
3. LOOK MA, NO PA	Some organisms reproduce by dividing, a method requiring only one parent (asexual).	Observation of ameba, paramecium, yeast, hydra, and onion root tip cells
4. DON'T PEAS COME IN CANS?	In sexual reproduction, two cells are involved and the offspring do not look like the parents.	Flower dissection; pollen tube formation
4A. THE EPIDEMIC NO ONE TALKS ABOUT	Venereal disease is a serious problem of epidemic proportions.	Reading about venereal diseases
5. THAT'S USING THE OLD BEAN	A pattern of inheritance can be observed over a period of generations.	Analyzing a series of bean crops
6. LET'S HAVE A PEA PICKIN' TIME	The pattern of inheritance can be predicted.	Analyzing a series of pea crops
7. WILL YOUR PREDICTION GO UP IN SMOKE?	The environment can affect the appearance of an inherited feature.	Examining genetic tobacco seedlings
8. WHAT'S A CLEAR CHIP WORTH?	Each offspring receives one "bit of information" for each feature from each parent.	Selecting plastic chips which represent features; model building
9. IT'S A DOG'S LIFE	One "bit of information" can dominate and hide another "bit of information."	Review of Investigations 5 to 8; plastic chips
10. IT TAKES BRAINS TO GAMBLE	You can determine the odds on the features an offspring will inherit.	Calculating odds
11. WRINKLED PEAS FOR DINNER?	A "bit of information" can direct the activities of a cell.	Conversion of sugar to starch with pea seed enzyme
12. I AM THE SECRET OF LIFE	The hereditary "bits of information" are carried on the chromosomes (as a chemical substance called DNA).	Observing chromosomes; karyotyping

Investigation 1 is to be done concurrently with Investigation 2. The time period shown above is to be shared with Investigation 2. Look ahead and plan both investigations together.

PURPOSE: Develop the concept that life comes from previous life.

DEVELOPMENT: The student will observe tubes of beef soup that have been treated differently, looking for signs of life. The student will infer from his observations that life can only come from previous life.

HIGHLIGHTS: There are two high points in this investigation. First, the student finds that no life appears in the tube with the crooked tubing, even though it is open to the air.

Secondly, the student is asked in question 12 to compare tubes 3 and 4. Both tubes allow air to enter, but no life appears in 4. Therefore, he must rule out spontaneous generation and infer that some life form is present in the air.

LOOK AHEAD: Begin Investigation 2 the day after you start Investigation 1.

MATERIALS (for each team of two or four)

- Four culture tubes, about 15 x 125 mm
- Cotton, to plug tubes
- Aluminum foil and string, to cover one tube
- Glass tubing, about 25 cm
- Test tube rack

MATERIALS (for teacher)

- Beef bouillon or nutrient broth (Difco, ¼ lb bottle)
- Pressure cooker to sterilize tubes and soup
- Saucepan to cook soup or broth
- Bunsen burner with wing top
- Triangular file
- Graduated cylinder
- Balance

Preparation of Materials (for each team of two or four)

Pour 10 ml beef soup into each of four culture tubes. Make nutrient broth or bouillon according to instructions on package.

Test tube 1 should be left open. Place a cotton plug in tubes 2, 3, and 4. Cover and tie tube 2 with aluminum foil. Insert a straight, glass tubing in tube 3. Use as wide a diameter of glass tubing as possible. Insert an S-shaped glass tubing in tube 4.

Sterilize all four tubes in a pressure cooker at 15 lbs/sq. in. for 15-20 minutes. Store in the refrigerator and use within 24 hours. The tubes can be kept upright in a test tube rack or in a jar.

TEACHING TIPS

Responses to Expect: Some of the students will believe in spontaneous generation. Unless they see a difference in tubes 3 and 4, they may say that life originates from air. Tube 4 is the famous Pasteur swan-neck experiment. In this experiment, the microorganisms were trapped by the neck of the bent tube, but the air or "active principle" was allowed to enter the flask of broth.

Caution the students not to remove any of the plugs or blow into any of the tubes.

By the third day, the students will begin to complain about the odor of the soup. Guide the class to realize that decomposition is taking place.

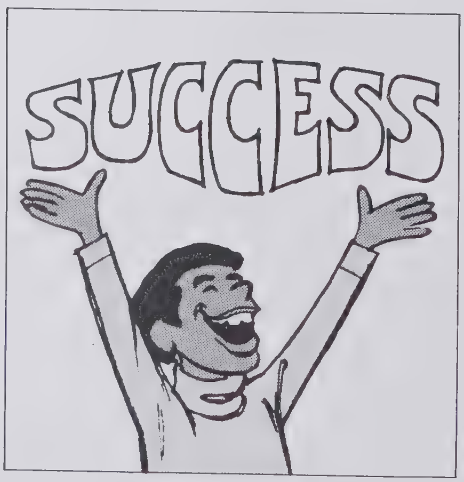
The students may inquire about the medium. Tell them that the liquid is regular beef soup. There should be nothing mysterious about the soup. It is just food for the bacteria.

Practical Hints: One set of test tubes for every group of four students is sufficient in one class. The same tubes can be reused for all other classes. Label the tubes with a group number so that the same set of tubes is observed each day by the same group of students. In addition, number each tube within the set to correspond with the diagram and table.

The students are to observe the tubes daily for 3-5 days. Each day's observations should be recorded in Table 1. The basic observation desired is either "clear" or "cloudy." The latter is an assumption that life is present. Since only a few minutes are necessary to observe the tubes each day, Investigation 2 is to be done concurrently.

All the tubes should be sterilized after the investigation is completed.

Discussion and Review: It is highly recommended that all the observations and questions be discussed in class. Every effort should be made to have the students understand and succeed in the first investigation.



Some of your students will experience difficulty in relating the cloudy beef soup with the presence of life. Try to elicit this response from them by reminding them of events they are familiar with, e.g., the spoiling of food.

ENRICHMENT

1. For those who have doubts about the presence of life in tubes 1 and 3, streak some of the contents on a Petri dish of nutrient agar. Use a control of known bacteria, such as *B. cereus* on another dish.

2. Have students prepare a paper on Pasteur's germ theory.

REFERENCES

Books and Articles

Biological Sciences Curriculum Study, *Biological Science: Molecules to Man.* Boston: Houghton Mifflin, 1968, Chapter 4.

Conant, J.B., ed., "Pasteur's and Tyndall's Study of Spontaneous Generation," *Harvard Case Histories in Experimental Science.* Cambridge, Mass.: Harvard University Press, 1959.

Gabriel, M., and S. Fogel, eds., *Great Experiments in Biology.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1955.

Oparin, Alexander I., *The Origin of Life,* 2nd ed. New York: Dover Publications, Inc., 1953.

Wald, George, "The Origin of Life," *Scientific American,* August, 1954.

Multi-Media Aids

Life Only from Life: Lp records or tapes, Wilson Corp. SC1.

Origin of Living Things: Filmstrip, color, 40 frames, Popular Science 1536.

Water–Liquid Basis of Life: Filmstrip, color, 40 frames, Popular Science 1511.

Spontaneous Generation, Part I: Controlled Observations: 8 mm film loop, color, Encyclopaedia Britannica 81170.

Spontaneous Generation, Part II: Effect of Microorganisms in Air: 8 mm film loop, color, Encyclopaedia Britannica 81171.

Life: Present and Past: 18" x 13" prints, color, 6 prints, Ward's 77 W 0060.

Origin of Life: 8 mm film loop series, color, 5 loops, Ealing 89-9799/1.

POSSIBLE ANSWERS

1. Clear.

2. The completely sealed tube, "2," is the control; however, tube 3 can be considered a secondary control for tube 4.

3. Possible predictions: The soup will stay the same. The soup will become cloudy. Some of the soup will evaporate.

4. The soup will stay the same.

5. The soup will become cloudy. The soup will stay the same.

6. The soup will become cloudy. The soup will stay the same.

7. If any of the caps are removed or if you blow into the tubes, you may introduce foreign materials into the soup, which could affect the experiment.

TABLE NO. 1

OBSERVATIONS OF BEEF SOUP KEPT UNDER DIFFERENT CONDITIONS

Test Tube	Observations, by Dates				
	1/5	1/6	1/7	1/8	1/9
1. Sterilized, Left Open	Clear	Cloudy	Cloudy	Cloudy, Smells	Cloudy, Smells
2. Sterilized, Sealed	Clear	Clear	Clear	Clear	Clear
3. Sterilized, Straight Tube	Clear	Clear	Clear	Cloudy	Cloudy
4. Sterilized, S-Shaped Tube	Clear	Clear	Clear	Clear	Clear

8. Tubes 1 and 3 showed a change.

9. Some form of life is in the tube. (Some students may want to assume that only a chemical change has taken place, but question them as to why the change did not take place in tubes 2 and 4. This assumption will be based on a belief that life can originate from air itself.)

10. Tube 3 turned cloudy and tube 4 remained clear.

11. Some form of life is in tube 3 but not in tube 4.

12. Life cannot originate from air itself, because air entered tube 4 and no change occurred.

13. The crooked tubing must have trapped whatever forms of life were floating in the air.

14. Yes, because in the tubes that are open, "1" and "3," life appeared. But in the tube that is sealed, "2," no life appeared. In the tube that has a trap, "4," no life appeared.

15. The life had to come from an existing form of life.

16. Life must come from previous life.

CONCEPT SUMMARY: Life comes from previous life.

This investigation is to be done concurrently with Investigation 1. The time period noted above is shared with Investigation 1.

PURPOSE: Develop the concept that the size of a population can increase very rapidly.

DEVELOPMENT: The student will make a geometric calculation showing the growth of a penny and observe an overpopulated tube of bacteria. From his data and observations, he will be asked to discuss the ramifications of population control.

HIGHLIGHT: In part B, the students see live evidence of the disastrous effect of overpopulation. Subsequent discussion of human population control should prove meaningful.

LOOK AHEAD: Order the live materials and suggested audio-visual aids for Investigation 3.

MATERIALS (for each team of two or four)

One culture tube[1]
Beef bouillon[2]

MATERIALS (for teacher)

Saucepan
Graduated cylinder
Balance

Preparation of Materials (for each team of two or four)

1. Tube 1 from Investigation 1 can be used concurrently in this investigation. It is recommended, however, that a separate tube be made because it will eliminate confusion and the dilution should be greater for better results.

2. To prepare the beef soup, add 10 times the amount of water specified in the directions on the package. (This thinner broth will deplete the food supply for the bacteria sooner.) Add 10 ml of this diluted beef soup to each culture tube.

Do not sterilize the tube. Prepare the soup an hour or two before class, and pour it into unsterilized tubes.

TEACHING TIPS

Responses to Expect: You may have some students who cannot add numbers, especially large ones. Help them. This is not a lesson on how to add.

Expect opposition to any suggestion of population control. This will be especially true if the class comes from a disadvantaged area, where the birth rate is high. Let the students see the problem and generate their own solutions.

A student may point out that the bacteria clustered in the bottom of the test tube do not prove death, only settling. You will have to tell the class that this is death.

Practical Hints: Do not start this investigation until the day after you start Investigation 1. By this time the student should understand the nature of the tubes of soup.

An excellent way to introduce Investigation 2 is to announce, "I am going to give someone one million dollars." Then hand someone about 162 sheets of paper on which have been mimeographed "$" signs. If you use elite type, you can cut about 6200 "$" signs on one stencil. Besides being an amusing opening device, this brings home the concept of a million. Spread the 162 pages on the floor or hang them on the wall; the impact is striking.

Immediately follow with the question that opens the investigation. Take a vote. You should have a divided class. You will have those who are now favorably impressed with the concept of a million and would surely accept a million dollars a day for 33 days. Then there will be those who suspect a trick—those who are more suspicious after the discrepant events in Idea 1, and those who have heard of geometric progression. They will take the doubling of the penny.

Let the students calculate the answer and determine who will be richer. The truth will be in the data and even the mathematicians will be surprised. You're better off with $30 million dollars for the month, but after 33 days, the penny comes out ahead. On the 33rd day, a penny would grow to $42,949,672.96.

After the students finish their calculations, post an adding machine tape of the answer. Use an adding machine that prints out the subtotal. This will produce a simpler tape to read.

If you choose to use a separate tube in part B, as is recommended, label this tube, "Investigation 2," in order to keep it separated from tube 1 in Investigation 1.

The students are to observe the color or condition of the tube for about five days. The tube should be cloudy the second day. By the fourth or fifth day, depending on the temperature of the room, the tube should suddenly be clear again. The bacteria will have overpopulated; the food supply will have dwindled; and the waste products will have killed all the bacteria. The dead bacteria will be visible as a residue at the bottom of the tube.

It is suggested that you show the movie, *Standing Room Only.*

Discussion and Review: Both sides of the population control problem should definitely be explored and discussed. Note that the student is free to take a stand on either side.

To assist you in your discussion of the question of population control, you can obtain additional information from:

Population Crisis Committee
1730 K Street
Washington, D. C. 20006

Planned Parenthood Federation of America, Inc.
515 Madison Avenue
New York, New York 10022

Also, see "Birth Control and the Negro Woman," *Ebony Magazine,* March, 1968. This article outlines many of the militant-black reasons for opposing birth control.

An exhaustive list of references and organizations is available from Dr. John H. Thomas, Department of Biological Sciences, Stanford University, Stanford, California 94305.

The most outspoken proponents of birth control are a group at Stanford University headed by Dr. Paul R. Ehrlich. Since this is not an organized group, free literature is not available. However, Dr. Ehrlich's view can be found in *The Population Bomb.*

ENRICHMENT

1. Produce a collage depicting the consequences of overpopulation.
2. Make a study of animal population growths such as the flight of the lemming.

REFERENCES

Books and Articles

Borgstrom, G., *The Hungry Planet.* New York: The Macmillan Co., 1967.

Ehrlich, Paul R., *The Population Bomb.* New York: Ballantine Books, 1968.

Paddock, William, and Paul Paddock, *Famine–1975! America's Decision, Who Will Survive.* Boston: Little, Brown & Co., 1967.

Shepard, P., and D. McKinley, *Subversive Science: Essays Toward an Ecology of Man.* Boston: Houghton Mifflin, 1968.

Multi-Media Aids

A Bacterial Growth Curve: 8 mm film loop, color, Encyclopaedia Britannica 81182.

Standing Room Only: 16 mm, color, 28 min., Modern Learning Aids. From the "Century 21" TV Series sponsored by Union Carbide Corp.

Population Ecology: 16 mm, color, 19 min., Encyclopaedia Britannica 2144.

POSSIBLE ANSWERS

1. The students have two choices, both equally valid.
2. 33 million dollars.
3. $5,368,709.12 at the end of 30 days, but $42,949,672.96 on the 33rd day.
4. The color or condition of the food is clear.
5. After several days, the soup became cloudy. Then the soup became clear again, but a whitish deposit settled to the bottom of the tube.
6. The bacteria multiplied, overpopulated, consumed all of the food, produced poisonous waste products, and died.
7. A population can overpopulate and kill itself.

CONCEPT SUMMARY: A population can multiply very rapidly. *Or,* a population can overpopulate and kill itself.

TABLE NO. 1

THE INCREASE OF A PENNY THAT IS DOUBLED DAILY

DAY	Amount	DAY	Amount	DAY	Amount
1	.01 x2	12	20.48	23	41,943.04
2	.02 x2	13	40.96	24	83,886.08
3	.04	14	81.92	25	167,772.16
4	.08	15	163.84	26	335,544.32
5	.16	16	327.68	27	671,088.64
6	.32	17	655.36	28	1,342,177.28
7	.64	18	1,310.72	29	2,684,354.56
8	1.28	19	2,621.44	30	5,368,709.12
9	2.56	20	5,242.88	31	10,737,418.24
10	5.12	21	10,485.76	32	21,474,836.48
11	10.24	22	20,971.52	33	42,949,672.96

TABLE NO. 2

OBSERVATIONS OF BEEF SOUP

Dates	Observations
April 3	Clear
April 4	Clear
April 5	Cloudy
April 8	Cloudy, smelly
April 9	Cloudy, smelly
April 10	Cloudy, smelly
April 11	Clear, smelly
April 12	Clear, smelly

BIOLOGY IDEA 3: GENETICS, Investigation 3 (2-4 periods)

PURPOSE: Develop the concept that some organisms reproduce by dividing.

DEVELOPMENT: The student will observe the reproduction of ameba, paramecium, yeast, hydra, and onion root cells. The student will infer from his observations that some organisms only need one parent to reproduce.

HIGHLIGHT: The climax comes in question 12 when the student is asked to explain the title of the investigation. If the student can answer it, he understands the concept of asexual reproduction.

LOOK AHEAD: Prepare sugar-agar plates and collect simple flowers for Investigation 4.

MATERIALS (for each team of two)

- Culture of live ameba (optional)
- Culture of live paramecium (optional)
- Culture of live yeast[1]
- Culture of live hydra
- Prepared slide of onion root tip, showing mitosis
- Microscope slide
- Cover slip
- Microscope

MATERIALS (for teacher)

- Film loop of ameba reproducing (optional)
- Film loop of paramecium reproducing (optional)
- Slide series of mitosis in onion root (optional)

Preparation of Materials

1. To prepare a culture of yeast, dissolve one package dry yeast and 125 g brown sugar in a liter of water. Stir and store overnight in a warm, dark place.

TEACHING TIPS

Responses to Expect: Expect impatient remarks from the students when they try to observe fission in the ameba or paramecia. Fission does not occur instantly, frequently, or on cue.

Practical Hints: Review the last investigation on overpopulation, with emphasis on the rapid reproduction of bacteria. Don't tell the students how the bacteria reproduce, since they are asked to predict this method of reproduction in question 2.

Reproduction is a difficult subject to teach because its observation requires proper conditions and a patient observer. For this reason, the use of live ameba and paramecium is difficult. If at all possible, use film loops or slides. Some are listed under References.

Rather than using prepared slides showing mitosis in onion root tips, your students can prepare their own. If you use one of the two kits listed under References, the preparation time will be minimal.

If you do not wish to expend the money for prepared slides, mitosis kits, or color transparencies, you can prepare your own according to the directions in the paper by Cole and Mertens.

Discussion and Review: All of the questions are basically alike. The thrust is toward reproduction by division.

Question 10 concerning the number of "parents" requires some explanation. Emphasize one nucleus as a parent. (Don't confuse the students with hermaphroditic reproduction from one parent.)

Build for the climax in questions 11 and 12. If the students do not know the term for question 13, tell them. It's only terminology.

ENRICHMENT

1. Have students prepare their own onion root tip slides.
2. Make cuttings of plants, such as *Coleus* or *Geraniums* to illustrate other forms of asexual reproduction.

REFERENCES

Books and Articles

Cole, Ronald L., and Thomas R. Mertens, "A Laboratory Exercise Demonstrating Chromosome Morphology and Number," *American Biology Teacher*, February, 1966, p. 114.

Flagg, Raymond O., and William R. West, "Plant Mitosis and Cytokinesis," *Carolina Tips,* June, 1969.

Mazia, Daniel, "How Cells Divide," *Scientific American,* September, 1961.

Swanson, Carl P., *The Cell,* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Wilson, G.B., *Cell Division and the Mitotic Cycle.* New York: Reinhold Publishing Corp., 1966.

Multi-Media Aids

Amoeba Proteus: 8 mm film loop, color, Ealing 81-5019/1.

The Dividing Cell: 8 mm film loop, color, Ealing 81-5936/1.

Budding of Yeast Cells: 8 mm film loop, color, Ealing 81-4285/1.

Paramecium Aurelia: Part 2–Reproduction: 8 mm film loop, color, Ealing 81-5035/1.

Amoeba-Fission: 8 mm film loop, color, Encyclopaedia Britannica 80092.

Bacteria: Reproduction: 8 mm film loop, color, Encyclopaedia Britannica 80695.

Chromosomes–Onion Root Tip Preparation: 8 mm film loop, color, Encyclopaedia Britannica 81194.

Elementary Mitosis Kit: Carolina Biological 20-1000.

Mitosis in Onion Root Tip: 2" x 2" slides, color, 12 slides, Carolina Biological 115.

Plant Mitosis: Filmstrip, color, 54 frames, Carolina Biological 52-1910.

Mitosis Kit: General Biological 78-6, or Lab-Aids, Inc. 9.

Plant and Animal Mitosis: Micro-slide and viewer set, National Teaching Aids.

POSSIBLE ANSWERS

1. The lack of food and accumulation of waste products would cause the bacteria to die faster than they could multiply.
2. By division.

Space *a:* Student drawing.

Space *b:* Student drawing.

3. One parent.
4. By producing a bud.
5. One parent.

6. By producing a bud.
7. One parent.
8. They divide to increase in number and replace the dead cells.

Space *c:* Student drawing.

9. They are in the process of dividing.
10. One parent.
11. Some organisms reproduce by dividing or budding from one parent.
12. There is only one parent involved.
13. Asexual.

CONCEPT SUMMARY: Some organisms reproduce by dividing, a method requiring only one parent.

Have plates of sugar-agar prepared. Try different concentrations beforehand to see which works best with the pollen you use.

PURPOSE: Develop the concept that some organisms are produced by the fusion of two cells and that the offspring need not resemble the parents.

DEVELOPMENT: The students will dissect a flower and observe the growth of pollen tubes.

They will compare this mode of reproduction with asexual reproduction, and with sexual reproduction in animals.

HIGHLIGHTS: The subject of sex itself is a highlight, especially human reproduction (part C).

In question 12, the student discovers that the offspring in sexual reproduction do not always resemble the parents. This sets the stage for the 8 investigations that follow Investigation 4A.

LOOK AHEAD: Begin germination of the tobacco seedlings for Investigation 7 ten days ahead.

MATERIALS (for each team of two)

- Flower, one that shows clearly all the desired structures[1]
- Razor blade (single-edge recommended)
- Hand lens (optional, but recommended)
- Petri dish of sugar-agar[2]
- Bean seeds, one each of assorted varieties such as those used in Investigation 5[3]
- Pea seeds, one each of assorted varieties such as those used in Investigation 6[3]

MATERIALS (for teacher)

- Saucepan to prepare sugar-agar solution
- Burner or hot plate
- Graduated cylinder
- Balance
- Cardboard or wood block (optional)
- Plastic wrap (optional)

Preparation of Materials (for each team of two)

1. Any kind of simple flower will do. The authors have found that fuchsia works best for them. They are not only plentiful on one bush, but also easy to dissect.

2. To make the sugar-agar dishes, use 1.5 g agar for every 100 ml of water. Bring this to a boil and add 2-5 g sugar. It is recommended that different concentrations of sugar (2-5%) be made because different kinds of pollen grow tubes at different sugar concentrations. Occasionally, it may be necessary to go as high as 10%. Nonetheless, *try this out beforehand.*

3. The peas and beans can each be placed on a piece of cardboard and covered with plastic wrap. Tape the wrap on the back of the cardboard, or seal the seeds in clear, plastic sandwich bags.

TEACHING TIPS

Responses to Expect: If students know this is a lesson on sexual reproduction, they may balk at the thought of dissecting a flower. They may respond with, "We know all that," until they are challenged with the task of finding the eggs and figuring out how the pollen meets the eggs.

This lesson does not purport to answer all the questions on human sexual reproduction. If you choose to go beyond the lesson, students may come forth with better questions if they can leave anonymous questions in a box.

Practical Hints: In order to protect the lab desks from scratches, it is recommended that the students dissect their flowers on heavy cardboard or wood blocks.

It is highly recommended that the peas and beans be sealed according to the suggestion given above. The advantages to this method are: (1) the students cannot throw the seeds around, (2) they can be collected and passed on to the next class, and (3) they are instantly visible for comparison.

The subject of reproduction should be discussed as normally as you would discuss any other bodily system. Don't prewarn the students that the subject is coming.

Discussion and Review: You should assume that the students are not aware of the life cycle of a flowering plant. Be sure they see how the seed fits into the entire cycle.

Be sure to raise the following questions, as they provide continuity to the investigations that follow:

a. What is the purpose of reproduction?

b. Does an organism have to reproduce?

c. How does an organism develop from a single cell?

d. How are features passed on from generation to generation?

The purpose of the entire Idea is genetic continuity, not reproduction. Therefore, close the investigation by emphasizing questions 13 and 14. Stress the fact that sexual reproduction often produces offspring that are unlike the parents. Then ask the students to hypothesize why this is so. This will provide a good transition to Investigation 5.

ENRICHMENT

1. Compare cross-pollination and self-pollination in plants.
2. Trace the types of maternal care in the various classes of animals.

REFERENCES

Books and Articles

Allen, R.D., "The Moment of Fertilization," *Scientific American,* July, 1959.

Austin, Collin, *Fertilization.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1965.

Corner, George W., *Ourselves Unborn.* New Haven, Conn.: Yale University Press, 1944.

Gramet, Charles, *Reproduction and Sex in Animal Life.* New York: Abelard-Schuman, Ltd., 1962.

Grant, V., "The Fertilization of Flowers," *Scientific American,* June, 1951.

Knepp, Thomas H., *Human Reproduction: Health and Hygiene.* Carbondale, Ill.: Southern Illinois University Press, 1967.

Koller, Dov, "Germination," *Scientific American,* April, 1959.

Michelmore, Susan, *Sexual Reproduction.* Garden City, N.Y.: The Natural History Press, 1965.

Monroy, Alberto, *Chemistry and Physiology of Fertilization.* New York: Holt, Rinehart and Winston, 1965.

Monroy, Alberto, "Fertilization of the Egg," *Scientific American,* December, 1950.

Pincus, G., "Fertilization in Mammals," *Scientific American,* March, 1951.

Reynolds, S.R.M., "The Umbilical Cord," *Scientific American,* July, 1952.

Rosenfeld, Albert, *The Second Genesis: The Coming Control of Life.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969.

Zahl, P.S., "The Evolution of Sex," *Scientific American,* April, 1949.

Multi-Media Aids

Animal Reproduction: 8 mm film loop set, color, 8 loops, Ealing 89-9922/1.

Fetal Pig: Part 4–Urinary and Reproductive Systems: 8 mm film loop, color, Ealing 81-0648/1.

Growth and Pollination of Corn: 8 mm film loop, color, Ealing 81-9698/1.

Human Reproduction and Birth: 8 mm film loop set, color, 6 loops, Ealing 89-9914/1.

Pollen Release: in Zea Mays: 8 mm film loop, color, Ealing 81-5688/1.

Pollen Tube Growth: 8 mm film loop, color, Ealing 81-5696/1.

Reproduction, Genetics, Breeding: Filmstrip set, color, 6 filmstrips, Popular Science B-5.

POSSIBLE ANSWERS

Space *a:* Check labeling of male reproductive organ and pollen.

Space *b:* Check labeling of female reproductive organ, ovary, and eggs.

Space *c:* Drawing of pollen grains in a sugar-agar plate.

Space *d*

Courtesy Carolina Biological Supply Co.

1. There are tubes growing out of the pollen grains in drawing *d.*
2. Yes. By wind or insects.

3. A sweet solution.
4. It would cause the pollen grains to produce long tubes.
5. The long tube connects the pollen grain to the egg cell.
6. Sexual.
7. The union of two cells.
8. No, they are of different shapes, sizes, and colors.
9. No, they are of different shapes, sizes, and colors.
10. Sexual reproduction.
11. They look like the parents.
12. They do not always look like the parents.
13. Two.
14. They often differ from the parents.

CONCEPT SUMMARY: In sexual reproduction, two cells are involved and the offspring do not always look like the parents.

PURPOSE: Develop the concept that venereal disease is a serious problem of epidemic proportions.

DEVELOPMENT: The students will read about and discuss the problem of venereal disease.

MATERIALS: Films concerning VD, see References (optional)

TEACHING TIPS

Responses to Expect: Expect a reluctance to discuss the subject. Give the students the opportunity to place questions in a box. In this way, their questions will be answered and group discussion may be stimulated.

Practical Hints: Invite a local physician or nurse to discuss the medical aspects of venereal disease.

Discussion and Review: This investigation does not follow the pattern of other IIS investigations. There is no concept to discover. The problem is serious.

The topic of venereal diseases has traditionally been a hush-hush subject in schools. When you consider the frightening statistics, the number of mental cases it ultimately produces, and the amount of time, money, and effort spent on lesser diseases, the time has come to reveal the epidemic proportions of the problem.

There is no question that we live in an increasingly permissive society. The "pill" has probably added to an increase in sexual contacts. Students should be made aware that the disease can be treated and cured only if detected early.

ENRICHMENT

Read *What You Should Know About VD–and Why.*

REFERENCES

Books and Articles

Schneider, Robert E., *Handbook on Venereal Disease.* Rockleigh, N.J.: Allyn and Bacon Inc., 1968.

Webster, Bruce, *What You Should Know About VD–and Why.* New York: Scholastic Book Services, 1967.

Multi-Media Aids

A Half Million Teenagers: 16 mm, color, 16 min., Churchill Films.

Innocent Party: 16 mm, color, 18 min., Calvin Productions.

Did you begin germination of the tobacco seedlings for Investigation 7?

PURPOSE: Develop the concept that a pattern of inheritance can be observed over a period of generations.

DEVELOPMENT: The students will observe quantitatively three generations of bean seeds, and construct a pedigree chart. From the pedigree chart and the ratios for each generation, they will see a pattern of inheritance.

HIGHLIGHT: The highlight comes in part B when the student discovers that a trait suddenly reappears in the second crop. He sees a pattern develop, although he cannot yet explain why.

LOOK AHEAD: Package the pea seeds for Investigation 6.

MATERIALS (for each team of two)

Three containers, such as vials or bags
Beans, brown (1½ cups); white (½ cup)
Small, plastic scoop, about 25 ml capacity

Preparation of Materials (for each team of two)

1. Label a container "Parents." It can be a vial, small test tube, baby food jar, envelope, or small bag. Into this container, place one brown bean and one white bean.

2. Label a second container "First Crop." Into this container, place 10-20 brown beans.

3. Label a third container, preferably a paper bag, "Second Crop." Into this container, place 1½ cups brown beans, ½ cup white beans, and a small, plastic scoop.

4. It is highly recommended that the method of sealing the seeds under a film of plastic be used (see Investigation 4). If you use this system, you can seal the entire six scoopfuls belonging to the "Second Crop," and reduce the chance of error.

TEACHING TIPS

Responses to Expect: Any student, slow or gifted, may be tempted to throw, pocket, or drop seeds. Sealing the seeds under plastic will eliminate this problem.

Some of the students may mechanically count the seeds and consider the activity completed. Yet the success of this investigation depends on the students thinking through the sequence of questions.

Practical Hints: The purpose of part A is to help the student understand the word *pattern*. This section (a repeat of Investigations 1 and 2 of Idea 1: *Inquiry*) is concerned with observation, and pattern, order, or consistency.

Every process listed on p. 15 of the Teachers Manual is used extensively in the next series of investigations. The most important process to be emphasized in this investigation is observation. Note the first question under part A, "How do you solve a problem?" The student must observe and recognize patterns, for answers seldom come in isolation. Learning comes when a pattern of information develops.

Explain what is meant by "Parents," "First Crop," and "Second Crop." This is not a lesson in life cycles, botany, or plant propagation. Explain that the samples represent three succeeding generations.

You should also explain "generation," "artificial pollination," and "pattern." The student must have a clear mental image of three generations. If not, he will struggle with the concept of generation and never see the intended concept of a "pattern of inheritance."

Investigations 5, 6, and 7 are a closely related block. Run all three as a smooth sequence to maintain a continuity of thought.

It may be more suspenseful to give out the containers one at a time. In this way the student will not be tempted to peek in anticipation of a question, such as "9."

Discussion and Review: Additional explanation on how to calculate a ratio (part B) will probably be needed.

In discussing the investigation, pay particular attention to the last four questions. They review the entire investigation. The concept summary is inherent in the last question.

For the next 6 investigations, the students will be seeing the 1:0 first-generation ratio and 3:1 second-generation ratio. Guide the class discussion so that they see this pattern. Then ask: "Why this pattern?" This will provide a transition into the next investigation.

ENRICHMENT

1. Have the students do a paper on Gregor Mendel.
2. Start the students on a *Drosophila* experiment that will produce the genetic pattern observed in the beans.
3. If you are in a rural school, have students bring in examples of pure strain crops.

REFERENCES

Books and Articles

Boyes, B.C., "The Impact of Mendel," *BioScience*, February, 1966.

Iltis, Hugo, *Life of Mendel*. New York: Hafner Publishing Co., 1932.

Papazian, Haig P., *Modern Genetics*. New York: W.W. Norton & Co., Inc., 1967.

Sturtevant, A.H., *A History of Genetics*. New York: Harper & Row, 1965.

Multi-Media Aids

Plant Life: Filmstrip series, color, 6 filmstrips, 51 frames each, Encyclopaedia Britannica 9050.

Experimenting with Drosophila: 8 mm film loop, color, Ealing 81-0762/1.

POSSIBLE ANSWERS

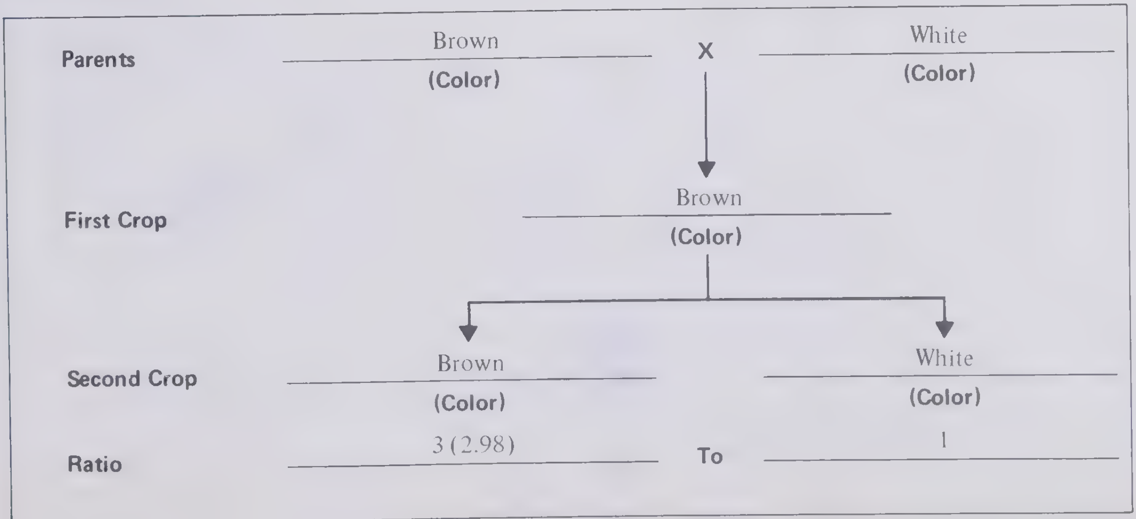
1. One is brown, the other is white.
2. It would be the same color as the parent.
3. Each bean comes from a pure strain.
4. The same color as the parent.
5. Because it also comes from a pure strain.
6. Brown.
7. The brown parent.
8. Yes. The feature for white color.
9. (Get the students to predict.)
10. Brown and white.
11. White color.
12. Brown appears more often; white, less often.

TABLE NO. 1 SAMPLE COUNT OF BEANS FROM A SECOND CROP

Counts	Greater Number Color: Brown	Lesser Number Color: White	Ratio
Your Total	162	56	2.9
Classmates Total	151	49	3.1
Classmates Total	176	61	2.89
Classmates Total	168	54	3.1
Grand Total	657	220	2.98

13. Three times.

DIAGRAM NO. 1



14. A pure strain.
15. One feature may disappear.
16. A feature may reappear.
17. Yes. All of one kind in the first crop and 3 to 1 in the second crop.

CONCEPT SUMMARY: A pattern of inheritance can be observed over a period of generations.

It is recommended that Investigation 7 be done concurrently.

PURPOSE: Develop the concept that a pattern of inheritance can be predicted.

DEVELOPMENT: The student will examine three generations of pea seeds, and compare the pattern of inheritance of the peas with the pattern observed in the beans.

In comparing the two similar patterns of inheritance, the student will infer that there may be a common pattern of inheritance that can be predicted for many forms of life.

HIGHLIGHT: The climax is reached when the student is about to open package 6 and senses a feeling of accomplishment because he knows what is inside. The pattern he sees developing resembles the pattern observed in the last investigation.

LOOK AHEAD: Order the glucose-1-phosphate now if you plan to do Investigation 11. It is an optional investigation.

MATERIALS (for each team of two)

- 6 small envelopes
- 285 smooth peas
- 75 wrinkled peas
- Petri dish

Preparation of Materials (for each team of two)

1. Number the six envelopes and insert the following:
   - "1"–containing 60 smooth pea seeds
   - "2"–containing 60 smooth pea seeds
   - "3"–containing 60 smooth pea seeds
   - "4"–containing 60 wrinkled pea seeds
   - "5"–containing 60 smooth pea seeds
   - "6"–containing 45 smooth seeds and 15 wrinkled pea seeds
2. Use either envelopes with clasps to prevent the seeds from spilling out, or seal the seeds under plastic and place them in an envelope (see Investigation 4).

TEACHING TIPS

Responses to Expect: Students may want to examine all six envelopes at once, rather than follow the directions. Therefore, distribute the envelopes one at a time.

Practical Hints: Review the pattern of inheritance observed in the last investigation. Guide the students to see the similar genetic patterns in the beans and the peas.

Explain the terms "pattern," "inheritance," "mating" or "crossing," and "ratio." It may be necessary to explain the term "texture" to the students. Help them see that the peas are either smooth or wrinkled in texture.

Discussion and Review: The questions in part C are appropriate for class discussion. Keep in mind that this investigation is designed to reinforce the concept of *pattern* and the *predictability* of pattern. Subtly begin to raise the question of the cause of the pattern.

ENRICHMENT: See suggestions in Investigation 5.

REFERENCES

Books and Articles

Bonner, David M. and Stanley E. Mills, eds., *Heredity,* 2nd Ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Kormondy, Edward J., *Introduction to Genetics,* programmed self-instruction. New York: McGraw-Hill Book Co., 1964.

Randal, Judith, *All About Heredity.* New York: Random House, 1963.

Multi-Media Aids

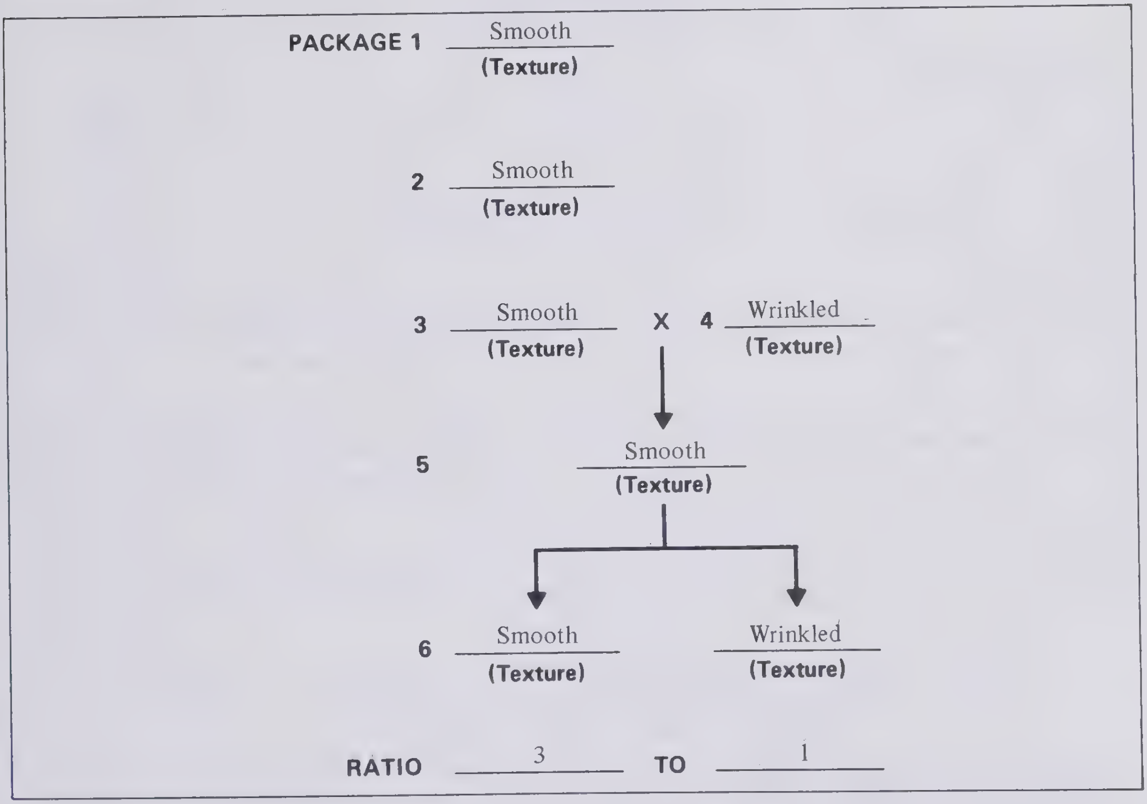
The Mystery of Life: 16 mm, color, 30 min., Modern Learning Aids. "Century 21" TV series sponsored by Union Carbide Corp.

POSSIBLE ANSWERS

1. The same as the parents.
2. All of one strain.
3. You would get both, but three times more of one kind than the other.
4. They are all smooth, yellow (or green), and round.
5. No.
6. No.
7. They are all smooth, yellow (or green), and round.
8. Smooth, yellow (or green), and round.
9. Smooth, yellow (or green), and round.
10. They are all smooth, yellow (or green), and round.
11. All smooth, yellow (or green), and round.
12. All smooth, yellow (or green), and round.
13. It is a pure strain.
14. All of them are wrinkled (or rough) and yellow (or green).
15. Wrinkled and yellow (or green).
16. It is a pure strain.
17. "1," "2," and "3" are smooth; "4" is wrinkled.
18. (Get the students to predict.) All seeds will be smooth. *Or,* all seeds will be wrinkled.

19. All are smooth.
20. The smooth parent.
21. Some will be smooth and others wrinkled.
22. There was a similar pattern in the beans in the last investigation.
23. Some smooth and some wrinkled.
24. Correctly. (He is not penalized, if incorrect.)
25. Three to one.
26. 45 smooth; 15 wrinkled.
27. Three to one.
28. The actual ratio agrees with the predicted ratio.
29. Yes. All are the same in the first crop, and a 3 to 1 ratio in the second crop.

DIAGRAM NO. 1



30. Offspring that look like the parents.
31. All will look like one parent.
32. Some will look like one parent, and others will look like the other parent. The ratio will be 3 to 1.
33. It can be predicted. We have seen two examples of 1:0 in the first crop and 3:1 in the second crop.

CONCEPT SUMMARY: The pattern of inheritance can be predicted.

This investigation is to be done concurrently with Investigation 6.

Do not start this investigation on a Thursday or Friday. See Teaching Tips.

A sample of dish 1 or 3 should be saved for illustration purposes in Investigation 9.

PURPOSE: Develop the concept that the environment can affect inherited traits.

DEVELOPMENT: The students will observe three dishes of tobacco seedlings, each grown under different environmental conditions. From their observations, they will be able to determine (by inference) the ancestry of the seedlings, and see the influence of the environment on inherited traits.

HIGHLIGHT: The students will observe three dishes of tobacco seedlings daily for five days. The highlight will come on the third and fourth days. One dish will be moved from the dark to the light on the second day. The students expect the plants to turn green on the third day, but they do not. This shakes their belief. On the fourth day, up to 75% become green.

From this puzzling observation, the student will see the effect of the environment on inherited features.

MATERIALS (for each team of two)

Three Petri dishes
Paper towel and scissors, or agar and water
Genetic tobacco seeds (3 green: 1 albino), 30-40 per dish

MATERIALS (for teacher)

Saucepan and spoon to cook agar
Burner or hot plate
Graduated cylinder
Balance
Plastic refrigerator bags

Preparation of Materials (for each team of two)

1. Ten days before this investigation, start to germinate the genetic tobacco seeds. If you have never germinated tobacco seeds before, you should know that they require at least ten days in a warm, moist environment. It is imperative that the seeds be kept moist. The dishes should be placed inside clear plastic refrigerator bags and sealed.

2. Prepare enough dishes for one class. The dishes can be shared and observed by succeeding classes during the day. You can cut down on the number of dishes by preparing only one dish 1 and 2. The teacher can keep both of these as controls for the entire class to observe (one student counts for the entire class). If possible, however, all three dishes should be prepared. Another way to cut costs is to make three dishes for each team of four students.

3. The simplest way to germinate tobacco seeds is to cut circles of blotter or paper towel to fit the Petri dishes. Wet the paper thoroughly. Then sprinkle 30-40 tobacco seeds evenly across the wet paper. Use a pencil or probe to distribute the seeds. The seeds are extremely small, so caution and patience are necessary.

If you choose not to use the wet paper method, you can make 20-25 ml of agar-water for each dish needed. Add 1.5 g agar to each 100 ml cold water; bring to a boil, stirring constantly. Dispense into separate Petri dishes. There is no need to sterilize the dishes or the medium. However, the dishes should be used immediately.

The purpose of the agar is to furnish water to the germinating seeds. There is no nutrient value in the agar. For this reason, adjust the volume of water after boiling.

4. Give every three dishes a group number. In turn, number each dish in the group. Store all the dishes marked "2" and "3" in a warm, dark place. Place all the dishes marked "1" under a source of light. (Use care with incandescent bulbs, for they may get too hot.)

Check the dishes daily and water the seeds, if necessary. Use an eyedropper for watering purposes. When checking dishes 2 and 3, do not expose them to light for more than 1-2 minutes.

TEACHING TIPS

Responses to Expect: If the Petri dish covers are removed to facilitate counting, caution the students against disturbing the plants with their pencils.

The students may need to be reminded to count the number of plants, not the number of leaves. However, the color of the leaves (green or albino) determines the color of the plant. In both green and albino seedlings, the stems and roots are cream-colored.

Practical Hints: Counting the plants should take ten minutes the first day, and no more than five minutes each day for the remaining four days. If you arrange your groups in teams of four, three students can each count one dish and the fourth can record the data. In addition, remind each of the students who count to count the same dish every day.

Since the activity only takes a few minutes each day for five consecutive days, this investigation should be started either on the last day of Investigation 5 or the first day of Investigation 6.

The key day in the sequence is the third day. Dish 3 is transferred from the dark to the light at the end of the second day. Before the students see the dish on the third day, they are asked to make a prediction as to what will happen to the plants under the changed environmental condition. They will probably predict that the plants will turn green. What they see happening in dishes 1 (mostly green because they are in the light) and 2 (all albino because they are in the dark) will lead them to make this prediction. Unless the plants are under a very intense light, it will require two days for them to turn green. Therefore, the plants in dish 3 will probably still be albino on day 3. The student then faces question 6 which asks him if he wants to change his prediction. Since we want to confront him with this discrepant event, you should arrange to begin counting on a Monday, Tuesday, or Wednesday. If you start on a Thursday, the plants in dish 3 will turn green over the weekend.

The teacher should maintain control over all the dishes between classes. Dispense the dishes for the short period of counting only. This will assure that each group gets the same set of dishes each day, and helps to reduce the possibility of damaging the plants.

Remember to transfer all the dish 3's to a source of light after the last class makes their second observation. If the plants in these dishes do not turn green on day 4, place them all under a fluorescent tube (Grolux preferred) or incandescent bulb, no more than 12" away.

Discussion and Review: The ideal time to discuss this investigation is right after you finish Investigation 6. Keep Investigations 5, 6, and 7 as a tight block. In Investigation 5, the student sees the 3 to 1 ratio in the second generation. In Investigation 6, he sees the same ratio and pattern. And now, in Investigation 7, he sees *only* the 3 to 1 ratio. From this he is asked to infer the pattern of the two previous generations. If he understood Investigations 5 and 6, he should have no problems with the required inference.

However, in the final review, stress the results in dish 3. As a result of the color change that appears in the plants, the student will deduce that the environment can influence the pattern of inheritance. Therefore, the key questions are "14," "22," "23," and "25."

ENRICHMENT

1. Let the students test the predictions they made in questions 11 and 12.
2. Similar experiments can be tried with genetic corn, sorghum, and soybean. These seeds are available from supply houses such as Carolina Biological and General Biological (Turtox).

REFERENCES

Books and Articles

Auerbach, Charlotte, *The Science of Genetics.* New York: Harper & Row, 1961.

Fast, Julius, *Blueprint for Life.* New York: St. Martin's Press, Inc., 1964.

Haffner, Rudolph, *Genetics, the Thread of Life.* Columbus, Ohio: American Education Publications, 1962.

Multi-Media Aids

The Thread of Life: 16 mm, color, 60 min., Bell System. Available from local telephone company or Modern Learning Aids.

POSSIBLE ANSWERS

1. Most of them will be green. Some will be albino.
2. All of them will be albino.
3. Most of them will turn green. Some will remain albino.
4. Since the plants in dish 1 were mostly green and they were in the light, I am predicting that the plants in dish 3 will also turn green when in the light.
5. The plants in dish 3 are all still albino. This does not compare favorably with the prediction made in question 3.
6. I will not change my prediction because more light is necessary. *Or,* I will change my prediction because once these plants are grown in the dark, they will always stay albino in appearance.
7. The 3 green to 1 albino result found in dish 3 compares favorably with the prediction. *Or,* the results contradict my prediction.
8. I predicted correctly because I recognized the 3 to 1 pattern seen previously when I observed the peas and beans. *Or,* I predicted incorrectly because I failed to recognize the 3 to 1 pattern seen previously.
9. The 3 to 1 ratio is a familiar ratio seen previously. 75% of the plants turned green because they inherited the ability to produce a green color in the leaves when exposed to light. The albino plants do not have the inherited ability to produce a green color, even in the light.
10. All the plants in dish 2 were albino because the plants were kept in the dark continually.

TABLE NO. 1

COUNT OF TOBACCO SEEDLING COLORS KEPT UNDER DIFFERENT CONDITIONS

Day	Dish Number	Condition	Number of Each Color		Ratio
			Green	Albino	
1	1	Light	16	6	2.6:1
	2	Dark	0	17	0:1
	3	Dark	0	21	0:1
2	1	Light	23	8	2.8:1
	2	Dark	0	26	0:1
	3	Dark	0	29	0:1
3	1	Light	25	9	2.7:1
	2	Dark	0	33	0:1
	3	Light	0	34	0:1
4	1	Light	26	9	2.8:1
	2	Dark	0	34	0:1
	3	Light	18	18	1:1
5	1	Light	27	9	3.0:1
	2	Dark	0	34	0:1
	3	Light	28	9	3.1:1

11. 75% would turn green and 25% would remain albino.
12. They would all lose their green color and turn albino in appearance.
13. The environment can affect the appearance of an inherited feature.
14. The environment.
15. 3 green to 1 albino.
16. In the second generation of peas and beans seen in the last two investigations.
17. The second generation.
18. All green.
19. One grandparent was green and the other albino.
20. All albino.
21. 3 green to 1 albino.
22. The change in light condition.

TABLE NO. 2

COMPARISON OF THREE PLANT FAMILIES

Generation	Bean Family	Pea Family	Tobacco Family
Parents	Brown-White	Smooth-Wrinkled	Green-Albino
First Generation	Brown	Smooth	Green
Second Generation	Brown-White	Smooth-Wrinkled	Green-Albino
Ratio	3:1	3:1	3:1

23. The environment.
24. No, the one in the good environment will probably have a better chance of growing to his full potential.
25. The environment.

CONCEPT SUMMARY: The environment can affect the appearance of an inherited feature.

BIOLOGY IDEA 3: GENETICS, Investigation 8 (2-3 periods)

PURPOSE: Develop the concept that each offspring receives one "bit of information" for a feature from each parent.

DEVELOPMENT: The student will use colored chips to represent the genotype of various parents and offspring. From the manipulation of the colored chips, the student will see that the inheritance of a feature is dependent on receiving one chip (a "bit of information") from each parent.

HIGHLIGHT: Science is a mental process. In this investigation, the students work with an abstract yet simple model which enables them to grasp a fundamental genetic principle.

MATERIALS (for each team of two)

Two paper bags, lunch bag size
Four brown plastic chips
Four clear plastic chips

Preparation of Materials

If you do not have an IIS equipment package, you can cut chips from pieces of clear and brown acetate, celluloid, or mylar (purchased from art supply stores). Each chip should be about 1 1/2 inches in diameter. Use a poker chip as a guide.

TEACHING TIPS

Responses to Expect: By about the third trial in Table 1, the students will start to complain that all the combinations are the same. Capitalize on this by praising the students, and pointing out how quickly they were able to see what happens when two different pure traits are crossed. The students don't need to complete the table. They only need to continue until they understand what the first generation will look like.

Practical Hints: Begin the lesson by reviewing the summary text that opens this investigation. Since the IIS program develops concepts sequentially, constant review is essential.

Use a model of the atom to illustrate how scientists construct models from something unseen. Explain why a mental model is needed to explain the pattern of inheritance. Finally, explain the concept of a model. This word is repeated in the next five investigations. By the end of this Idea, the student will ultimately form a simple model of Mendelian inheritance.

It is important that you offer maximum guidance for the rest of this Idea. The IIS program is not designed for students to work alone. Students will need help to think on the abstract level of building models.

Guide the students to understand what the chips represent. Some of the students may ask why the chips are returned to the bag after each trial. Rather than answering directly, give them all the chips needed to complete either Table 1 or 2 without returning the chips to the bag after each trial. Then ask them if their data are any different. Better yet, ask them to explain their answer.

Discussion and Review: The important concept is that each offspring receives *one* "bit of information" for each feature from each parent. To impress upon the students the correctness of this concept, allow them to try other possible models. Try *two* "bits of information" from one parent and *one* "bit of information" from the other parent; or, a two and zero or two and two model. The data will show that only a one-one model works.

Climax the investigation by discussing questions 11-14.

ENRICHMENT

1. Allow the students to try other possible models with the chips.
2. Have students do a paper on Mendel's principle of segregation.

REFERENCES

Books and Articles

King, Robert, *Genetics,* 2nd ed. New York: Oxford University Press, 1965.

Lerner, Marguerite Rush, *Who Do You Think You Are?* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963.

Stahl, F.W., *The Mechanics of Inheritance.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Winchester, A.M., *Genetics.* Boston: Houghton Mifflin, 1966.

Multi-Media Aids

Genetics: Mendel's Laws: 16 mm, color, 13.5 min., Coronet 1312.

Laws of Heredity: 16 mm, color, 15 min., Encyclopaedia Britannica 2073.

POSSIBLE ANSWERS

1. All brown chips. Because the brown feature is a pure strain.
2. All clear chips. Because the clear feature is a pure strain.
3. Because all the chips in one bag are the same.

TABLE NO. 1

RESULTS OF A PURE BROWN-WHITE CROSS

Trial	Combination of Chips	Overall color
1	Brown-Clear	Brown
2	Brown-Clear	Brown
3	Brown-Clear	Brown
4	Brown-Clear	Brown
5	Brown-Clear	Brown

4. One. Always brown and clear.
5. No. There is only one combination possible because all the chips in one bag are brown; all the chips in the other bag are clear.
6. All brown.
7. Brown.
8. Brown and clear.

TABLE NO. **2**

RESULTS OF A FIRST GENERATION BROWN-BROWN CROSS

	Possible Color Chip Combinations		
	Brown-Brown	**Brown-Clear**	**Clear-Clear**
Tally Marks	$\vert\vert\vert$	$\cancel{\vert\vert\vert\vert}$ $\vert\vert\vert\vert$	$\vert\vert\vert\vert$
Your Total	3	9	4
Classmates Total	4	8	3
Classmates Total	5	8	3
Classmates Total	4	7	5
Grand Total	16	32	15
OVERALL Color	Brown	Brown	Clear
Ratio	1	2.1	1

9. Three brown to one clear.
10. In the bean, pea, and tobacco plants.
11. "Bit of information."
12. Each parent to each offspring.
13. Each parent.
14. One "bit of information" from each parent.

CONCEPT SUMMARY: Each offspring receives one "bit of information" for each feature from each parent.

BIOLOGY IDEA 3: GENETICS, Investigation 9 (2 periods)

PURPOSE: Develop the concept of dominant and recessive features.

DEVELOPMENT: The student will analyze the reason for the pattern of inheritance observed in Investigations 5, 6, and 7. Using brown and clear plastic chips in his analysis, he will see that some features can dominate or hide other features.

HIGHLIGHT: This investigation summarizes Investigations 5 to 8. The highlight comes when the student sees that one reason for the pattern of inheritance seen in the bean seeds, pea seeds, and tobacco plants is that there are dominant and recessive features.

MATERIALS (for each team of two)

Two brown plastic chips
Two clear plastic chips

TEACHING TIPS

Responses to Expect: Students may find 4 pages of straight inquiry dull. This is a normal reaction. The best way to counteract the boredom and strenuous mental task of 32 questions is to discuss each section separately with the entire class. The teacher's role is most important in this investigation.

Practical Hints: Give the plastic chips to the students as they progress through the questions. It will help them visualize their answers.

Bring out samples of the bean seeds, pea seeds, and tobacco plants. Use these as visual reminders of the concepts learned in recent investigations. Have the students refer to Investigations 5, 6, and 7 in their folders, if necessary.

Discussion and Review: The key to understanding this investigation is in the last paragraph of part A. Give the students the brown and clear plastic chips. See if they can discover the concept of dominant and recessive "bits." Do not proceed to part B until you are sure that everyone sees the concept.

Let the students keep the plastic chips as they work through part B on their own. Then the entire class should discuss their answers. Use the plastic chips to illustrate the answers to many of the questions. Repeat this same procedure for parts C and D.

ENRICHMENT

1. Have students do a paper on Mendel's principle of independent assortment.
2. Have students do a family pedigree and see if they can find a pattern of inheritance.
3. Prepare a chart showing some features that are the result of blending rather than a definite dominant-recessive effect.

REFERENCES

Books and Articles

Merrell, David J., *Evolution and Genetics.* New York: Holt, Rinehart and Winston, 1962.

Stern, Curt, and E.R. Sherwood, *The Origin of Genetics.* San Francisco: W. H. Freeman & Co., 1966.

Multi-Media Aids

Genetics: Improving Plants and Animals: 16 mm, color, 13.5 min., Coronet 1324.

POSSIBLE ANSWERS

1. One chip.
2. Two chips, one from each parent.
3. A feature from one parent.
4. Two.
5. One.
6. Brown.
7. Clear.
8. Brown.
9. Two.
10. Two brown "bits."
11. Two white "bits."
12. One brown and one white "bit."
13. It is hidden by the dominant brown "bit."
14. Brown.
15. White.
16. White reappeared in the second generation.
17. Two.
18. Two brown "bits," or one brown and one white "bit."
19. Yes.
20. Two recessive (white) "bits."
21. Package 3, smooth; package 4, wrinkled.
22. Package 3, smooth "bit"; package 4, wrinkled "bit."
23. Smooth is dominant.
24. Three to one.
25. Two smooth "bits," or one smooth and one wrinkled "bit."
26. Smooth "bit" is dominant.
27. All green.
28. Two.
29. One green and one albino "bit."
30. Green is dominant.
31. Original parent, two green "bits"; other original parent, two albino "bits."
32. Dominant and recessive.

CONCEPT SUMMARY: One "bit of information" can dominate and hide another "bit of information."

BIOLOGY IDEA 3: GENETICS, Investigation 10 (2-3 periods)

PURPOSE: Develop the concept that odds can be determined on the features an offspring will inherit.

DEVELOPMENT: The student will use coins to develop some basic rules of probability. The class will then determine the percentages of some common inherited human features.

Using his knowledge of probability, the percentages determined for each feature, and a pedigree chart, the student will see that the appearance of a feature can be predicted.

HIGHLIGHT: The special feature of this investigation is the pedigree chart in part D.

LOOK AHEAD: Begin preparations for Investigation 11, if you plan to do this optional investigation.

MATERIALS (for each team of two)

Two coins (supplied by the students)
PTC paper[1]
Two brown plastic chips
Two clear plastic chips

Preparation of Materials

1. PTC paper can be purchased, or you can make your own at a considerable saving.

To make your own:

a. Add 650 mg phenylthiocarbamide to 1 liter water.
b. Boil to dissolve.
c. Soak paper towels in the solution.
d. After the towels dry, cut them into bite-sized pieces.

Serve with a piece of hard candy after students taste the PTC paper.

TEACHING TIPS

Responses to Expect: Students may become embroiled in an argument over the best odds in a coinmatching game. Let them generate predictions and test their predictions. While they do this, have them start thinking in terms of odds; e.g., 1 to 2, or 1 chance in 4, or 50-50 chance.

The level of abstraction in this investigation is high. Do each part separately and make full use of the activities to provide a change of pace and to illustrate the answers.

Practical Hints: Use plastic chips to represent the "bits" or features. Let students manipulate the chips on their desks as a means of visualizing the features. Put chips on a transparency projector so that they can see you manipulating the chips, too.

Duplicate the pedigree chart in part D on a transparency. Use it during the class discussion. Brown and clear plastic circles, matching the circles in the chart, can be used as a visual means of illustrating dominance, recessiveness, and the "bit of information" concept.

Discussion and Review: The class percentages in part C may not match the national percentages. Your sampling may be too small or it may be atypical. The national averages given may not match the racial content of your class. In some of the national averages given, we do not have data on blacks and Orientals. Nonetheless, the key question in part C is "18." If a figure repeats itself over and over again, we know that there is a mathematical basis for it.

The major point to stress is that odds or *chance* does not indicate an unknown quantity. When you flip a coin, you do know the odds for each side. This is true with genetic features, too. You may not know exactly which feature will appear, but you do know the odds. If you know the odds, you can make educated predictions.

Because class data are necessary, part C should be done with the entire class. Have the students do part D on their own before you begin a general discussion.

ENRICHMENT

1. Have the students roll one die and determine that each roll is an independent act. This is the law of probability that says that each event is independent.
2. Have the students roll two dice and determine that each roll is the product of two independent actions.
3. Give the students PTC paper to take home and have them design a pedigree chart of their own family.

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Roslansky, John D., ed., *Genetics and the Future of Man.* New York: Appleton-Century-Crofts, 1966.

Multi-Media Aids

Genetics: Human Heredity: 16 mm, color, 13.5 min., Coronet 1493.

POSSIBLE ANSWERS

TABLE NO. 1
RESULTS OF FLIPPING TWO COINS

Counts	Possible Combinations		
	Heads-Heads	Heads-Tails	Tails-Tails
Tally	~~IIII~~ ~~IIII~~ III	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ I	~~IIII~~ ~~IIII~~ ~~IIII~~ I
Total	13	31	16
Ratio	1	2.3	1.2

1. 1 time in 4. There are four possible ways for the coins to appear: heads-heads, tails-tails, heads-tails, tails-heads.
2. 1 time in 4. Same reason as in "1."
3. 2 times in 4. The heads-tails or tails-heads combination will probably appear two out of four times.
4. No. The odds are not even; it's 3 to 1 against the two-heads combination appearing.
5. One chance in four.
6. One chance in fifty-two.
7. One chance in thirteen.

8. 1 in 1. These parents will produce brown offspring because the brown will dominate the white.

9. Three chances in four. One chance in four. Three different combinations will cause the brown feature to appear; one combination will cause the white feature to appear.

10. Three chances in four. One chance in four. Three different combinations will cause brown eyes to appear; one combination will cause blue eyes to appear.

11. Two "bits of information" for blue eyes.

12. Two "bits of information" for brown, or one "bit of information" for brown and one "bit" for blue.

13. No. Each child received one "bit of information" for blue eyes from Kathleen.

14. Carl must have one "bit of information" for blue eyes and one "bit" for brown eyes.

15.-17. Class data. (The percentages in your class will probably not coincide with the national percentages. Explain that the variation is due to the small sampling taken.)

18. The same chances for the features to appear are passed on from generation to generation.

19. Two.

20. Two bits for nontasting.

21. Two.

22. Grandmother Lopez, Grandfather Martinez, Grandmother Martinez, Mother Lopez, José, Maria.

23. No. The taste "bit" would dominate.

24. Taste.

25. Nontaste.

26. One taste and one nontaste "bit."

27. Different.

28. Nontaste.

29. Taste.

30. Nontaste.

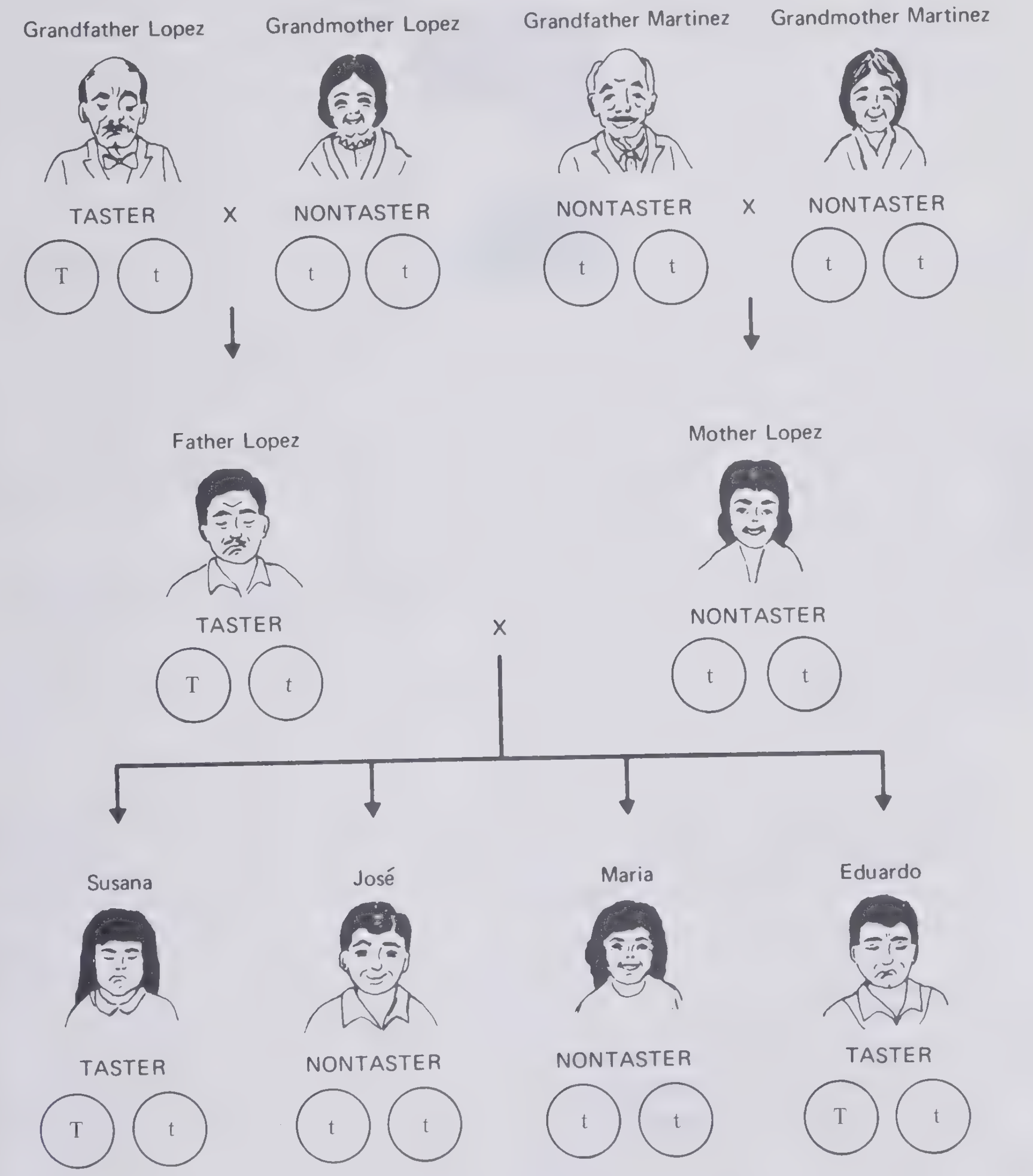
31. Yes. If Father Lopez's sister was a nontaster, then Grandfather Lopez had to have a nontaste "bit" as well as a taste "bit." A nontaster must have two nontaste "bits"–one from each parent.

32. Taster–one chance in two. Nontaster–one chance in two. There is one way to form a taster (Tt) and one way to form a nontaster (tt).

33. Odds.

CONCEPT SUMMARY: You can determine the odds on the features an offspring will inherit.

DIAGRAM NO. 1


Grandfather Lopez
TASTER
T t
X
Grandmother Lopez
NONTASTER
t t
Grandfather Martinez
NONTASTER
t t
X
Grandmother Martinez
NONTASTER
t t
Father Lopez
TASTER
T t
X
Mother Lopez
NONTASTER
t t
Susana
TASTER
T t
José
NONTASTER
t t
Maria
NONTASTER
t t
Eduardo
TASTER
T t

This is an optional investigation. The continuity of concepts will not be disrupted if it is omitted.

PURPOSE: Develop the concept of genes or "bits of information" directing the activities of a cell.

DEVELOPMENT: The student will apply drops of liquid from crushed smooth peas and wrinkled peas to a Petri dish of sugar-agar. The enzymatic action of the liquid from the wrinkled peas will change the sugar to starch, thus illustrating part of the "one gene—one enzyme" hypothesis.

HIGHLIGHT: The highlight comes just before question 1 when the student tests the sugar for starch and finds that starch has suddenly appeared in two of the four spots. This mystifying result culminates in question 15 which asks what directs a cell.

MATERIALS (for each team of two)

- Petri dish of nutrient agar[1]
- Glucose-1-phosphate, 1 to 1.5 g per class
- Marking pen or masking tape
- Smooth pea solution[2]
- Wrinkled pea solution[2]
- Two dropper bottles, or 2 jars and eyedroppers
- Lugol's solution, 5 ml
- Paper towels
- Microscope slide

MATERIALS (for teacher)

- Refrigerator (optional, but recommended)
- Mortar and pestle or blender (preferred)

Preparation of Materials

1. Add 2 g agar to each 100 ml of water. Stir and bring to a boil. Add 0.5 g glucose-1-phosphate to each 100 ml and stir to dissolve. Pour 10 ml into each Petri dish (one for each student pair). Do not sterilize. Refrigerate and use within 24 hours.

2. Grind 20 g or about 25 smooth peas in 80 ml water using a blender or a mortar and pestle. Grind 20 g or about 25 wrinkled peas in 80 ml water using a blender or a mortar and pestle. Let each solution settle, or strain each solution through many layers of cheesecloth. Use only the supernatant. Store in labeled bottles in a refrigerator. One bottle of each solution will suffice for all your classes. Each student pair will need only two drops from each bottle.

TEACHING TIPS

Responses to Expect: The concept of enzymatic action and biochemical change will be foreign to the students. They will probably attribute the presence of the starch to the diffusion of starch from the pea seed liquid into the agar. This notion is dispelled when they find starch in the smooth pea liquid but none in its corresponding section in the Petri dish.

Keep a close watch over the two containers of pea seed liquid and their droppers. If there is any mixing of the two liquids, discard them completely.

Practical Hints: Cost may be a major reason for omitting this investigation. It is, however, an exciting and dramatic reaction to watch. You will need 1.5 g of glucose-1-phosphate for each class. Five g cost about $8.50. The glucose-1-phosphate may be purchased from a supplier of biochemicals (e.g., CalBioChem, Los Angeles; Sigma, St. Louis; Schwarz/Mann, New York). It should be purchased within 30 days before use and stored under refrigeration.

In this investigation, the student will see sugar (glucose-1-phosphate) converted to starch. He is to infer that the conversion was caused by the pea extract. The factor in the pea extract is an enzyme which helps bond glucose (a monosaccharide) into a long chain of starch (a polysaccharide).

Explain to the students how you prepared the two liquids. Show them some smooth and wrinkled peas and remind them that these are the same peas used in Investigation 6. Be sure the students understand that the two bottles contain the "squeezed juice" from each kind of pea.

During the half-hour required for the sugar-starch conversion, explain the contents of the dish and bottles. This is also a good time to demonstrate the starch test on carbohydrate and noncarbohydrate samples. Finally, it would be helpful to give a simple explanation of sugars, starches, and carbohydrates.

Caution the students about the iodine solution. It can stain their clothing.

Discussion and Review: Discussion should center around part B. The concept to develop is that the "bit of information" directs an activity in a cell. The cell then does it. To put it another way, a "bit of information" doesn't do the work. It "tells" the cell what to make to do the work. In this case, the code directs the cell to make an appropriate enzyme. This, of course, is the Nobel prize-winning "one gene–one enzyme" hypothesis.

ENRICHMENT

1. Have students do a paper on the Beadle-Tatum "one gene–one enzyme" hypothesis.
2. Have students do a paper on the transfer of information from a virus to a cell.

REFERENCES

Books and Articles

Barish, Natalie, *The Gene Concept.* New York: Reinhold Publishing Corp., 1965.

Barry, J. M., *Molecular Biology: Genes and the Chemical Control of Living Cells.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Horowitz, Norman H., "The Gene," *Scientific American,* October, 1956.

Multi-Media Aids

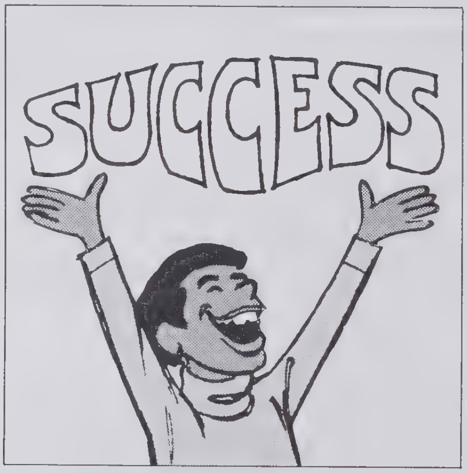
Gene Action: 16 mm, color, 16 min., Encyclopaedia Britannica 2138.

Genetics: Chromosomes and Genes (Meiosis): 16 mm, color, 16 min., Coronet 1492.

POSSIBLE ANSWERS

1. The two spots over the "W" or the side with the wrinkled pea liquid.
2. The two spots over the "W" or the side with the wrinkled pea liquid.
3. From the liquid drops or from the sugar-agar.
4. Both drops show the presence of starch.
5. Sugar.
6. From the sugar, because both liquids contained starch.
7. The liquid from the wrinkled pea seeds reacted with sugar to turn it into starch. (Much teacher guidance and class discussion will be needed for the students to grasp this idea.)
8. The ability to turn sugar into starch.
9. The inability to turn sugar into starch.
10. The "bit" that "tells" the seed to make a certain chemical substance.
11. The smooth seeds did not inherit the "bit" inherited by the wrinkled seeds.
12. To make a chemical substance that will turn sugar into starch.
13. The smooth seed is not capable of making the chemical substance.
14. The wrinkled peas are too starchy, and do not have the sweeter taste of the smooth peas.
15. A "bit of information."

CONCEPT SUMMARY: A "bit of information" can direct an activity in a cell.



BIOLOGY IDEA 3: GENETICS, Investigation 12 (3-4 periods)

PURPOSE: Develop the concept that the hereditary "bits of information" are carried on the chromosomes.

DEVELOPMENT: The student will make a human chromosomal karyotype (a chart of a chromosomal pattern). He will compare a normal karyotype with an abnormal karyotype, note the features that are inherited, and come to the conclusion that the hereditary code is carried on the chromosomes.

HIGHLIGHT: Until a decade ago the technique of karyotyping was unknown. Although the student will not be doing the complete procedure, pasting up the chromosomes is a simulation of an exciting new technique.

LOOK AHEAD: Order your supplies for the next Idea. Idea 4 makes considerable use of live specimens.

MATERIALS (for each team of two)

- Prepared mitosis slides, onion root tip
- Microscope
- Glue
- Scissors

TEACHING TIPS

Responses to Expect: The students may have some difficulty in matching the chromosomes in pairs, because they are not identical. Since the technique requires a trained technician, the students will need considerable help. This simulation will help them answer the questions.

Don't belabor the perfection of the karyotype. The important factor is the concept, not the technique.

You will definitely get a response in part C when the subject of LSD and chromosome breakage is introduced. Although the data thus far are not conclusive, the implications are evident.

Practical Hints: Review all of the text that precedes part A. Help the students see the relationship of this investigation to all of the previous concepts.

Keep all the prepared mitosis slides in a separate slide box and dispense them as needed. Check and count all slides as they are returned. Put away the slides and microscopes before continuing.

Explain the technique of karyotyping which was developed by Tijo in 1956. Under normal circumstances, a blood sample is cultured and stained to bring out the chromosomes in certain white blood cells. These isolated cells are then photographed and the photograph enlarged. The resulting photograph of 46 chromosomes (in no particular pattern) is then cut and the karyotype made. In 1960, an international standard numbering system was agreed upon.

The purpose of part A is to get the student to make an initial inference that the "bits of information" are on the chromosomes. There is no proof, only an inference.

The purpose of part B is to show the student what happens when the chromosomes are abnormal. Many students have the incorrect assumption that all diseases are caused by germs. Very few know about genetic diseases, which are also called inborn errors or metabolic errors. Some examples of genetic diseases are Down's Syndrome, diabetes, PKU, and sickle-cell anemia.

Discussion and Review: Conclude the entire Idea by reviewing all the concepts and by discussing part D. Should man tamper with his destiny? For years the scientific community, science teachers, and science textbooks have remained aloof from social problems. Many still do. This cannot be allowed to continue. What good are our scientific advances if our social advances cannot be matched accordingly? In fact, if our social problems destroy us, what good are any of our scientific advances?

ENRICHMENT

1. Construct a DNA model.
2. Have students do a paper on the social problem outlined in the last part.
3. Have students do additional library research on any of the genetic diseases mentioned.

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Borek, Ernest, *The Code of Life.* New York: Columbia University Press, 1965.

"LSD and Leukemia," *Time Magazine,* July 11, 1969, p. 38.

Macleish, John, and Brian Snoad, *Looking at Chromosomes.* New York: St. Martin's Press, Inc., 1958.

Wallace, Bruce, *Chromosomes, Giant Molecules, and Evolution.* New York: W.W. Norton, 1966.

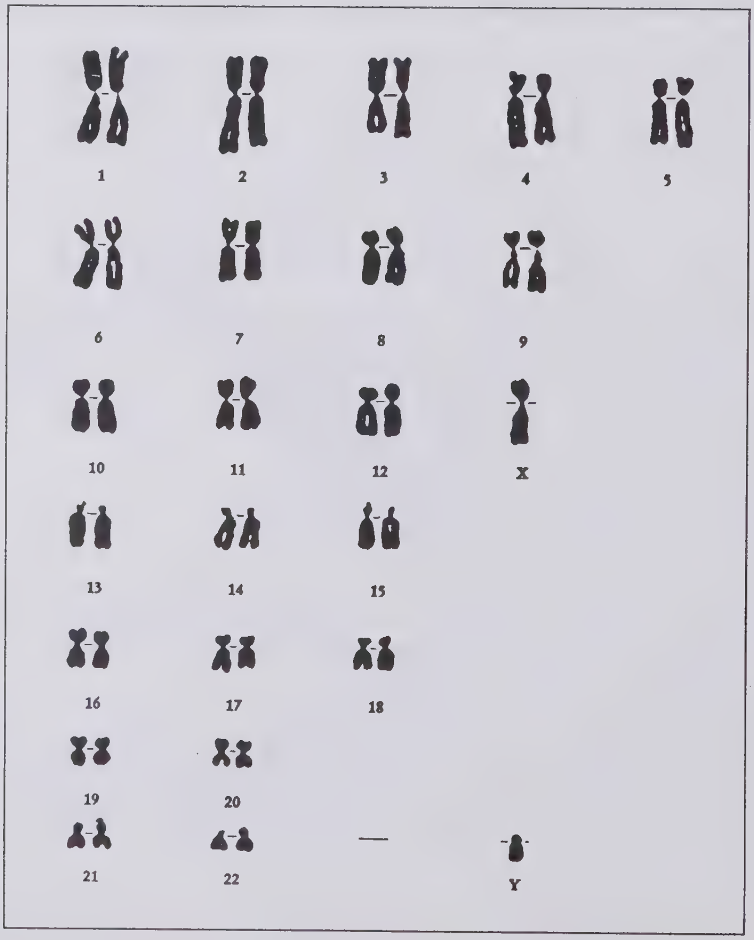
Multi-Media Aids

The Chromosomes of Man: 16 mm, black and white, 20 min., Encyclopaedia Britannica 2719.

DNA: Molecule of Heredity: 16 mm, color, 16 min., Encyclopaedia Britannica 1825.

POSSIBLE ANSWERS

CHART NO. 1



1. The 23rd pair of chromosomes are different. In my chart the 23rd pair are not matched. In the chart pictured the 23rd are matched.

2. The "bits of information" may be on the 23rd pair of chromosomes.

3. "Bits of information" may also be on the other 22 pairs of chromosomes.

4. There is an extra chromosome, a total of three, in box 21 of the chart pictured.

5. The "bits of information" that determine the inherited features may be on the chromosomes.

6. An incorrect "bit of information" can misdirect the operations of a cell, thus causing an inherited disease.

7. A "bit of information."

8. An incorrect message may come from the broken "bit of information."

9. It may be born with an inherited disease or deformity.

10. "Bits of information."

CONCEPT SUMMARY: The hereditary "bits of information" are carried on the chromosomes (as a chemical substance called DNA). (The latter phrase was not introduced to the student nor was the subject treated in any great detail. Any emphasis on DNA will depend on the intellectual level of the class, and the degree to which the teacher wishes to supplement the investigation.)

IDEA SUMMARY: All living things have passed on traits from generation to generation with a continuity of pattern.

Idea 4
Homeostasis

The idea of homeostasis is the theme of the fourth Idea in the IIS biology program. The students find this Idea particularly enjoyable and meaningful because it is basically about human physiology. However, it does not treat the human body as a collection of separate and isolated systems. Rather, the student will see the IDEA Summary that an organism is a dynamic individual and that:

LIFE IS A CONTINUOUS STRUGGLE TO KEEP VARIOUS PROCESSES AT A SUITABLE BALANCE.

There are ten investigations in this series. The first three investigations are centered around the concepts of stimulus and response. The next three are concerned with the idea that there are various optimum constant states in an organism. In Investigations 7-9, three of the body regulatory systems are introduced to show how the various optimum constant states are maintained. And in the last investigation, the general idea of homeostasis is summarized through the use of a card game.

Two entire investigations are devoted to the topics of smoking and drugs, subjects the students will find very relevant.

It cannot be stressed too much that the entire Teachers Manual for this section should be read beforehand. There is extensive use of live animals (snails, *Daphnia,* goldfish, chicks) and these should be preordered and planned for.

BIOLOGY: IDEA FOUR (HOMEOSTASIS)

Life Is a Continuous Struggle to Keep Various Processes at a Suitable Balance

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. ARE YOU GROOVY AND IN GEAR?	Living things must respond to a stimulus.	Response experiments with seeds, pulse rate, and snails
2. LET'S COOL IT	Different stimuli can cause different responses.	Heartbeat rate of Daphnia; capillary flow in a goldfish
3. NO SWEAT	Each response is made to keep the organism at a constant state.	Measuring sweat gland activity and body temperature
4. WE MUST WORK TOGETHER	Different body functions must work together to keep the body at a constant state.	Measuring pulse, breathing, and gas production rate
5. THE BIGGEST PUT-ON IN LIFE	Overstress can upset a constant state.	Smoking and breathing
6. KEEP YOUR COOL AND KEEP IT STEADY	Each body function operates best at its particular constant state.	Digestion of starch with enzymes
7. A REAL MOVING STORY	Membranes help the body to regulate its constant state.	Diffusion and osmosis
8. HOW'S YOUR BLOOD SUGAR?	Hormones help the body regulate its constant state.	Effect of hormones on seeds and chicks
9. WHAT'S THIS SCENE ALL ABOUT?	The nervous system coordinates the life functions necessary to maintain a constant state.	Drug abuse
10. THE GAME OF HOMEOSTASIS	Life is a continuous struggle to keep various processes at a constant state.	Academic game with cards

BIOLOGY IDEA 4: HOMEOSTASIS, Investigation 1 (4-5 periods)

Start the pea seeds germinating at least three days before this investigation.

Collect or order the snails needed for part C.

Commend the students for their successful completion of Idea 3.

PURPOSE: Develop the concept that organisms are capable of responding to a stimulus.

DEVELOPMENT: The students will plant germinated seeds that are oriented in different positions, count their own pulse rate and breathing rate before and after exercise, and plot the movement of a snail when a beam of light is shining on it.

From these three experiments, the student will see that different organisms can respond to changing conditions.

HIGHLIGHT: This investigation builds toward a climax with each succeeding experiment. Each activity is a highlight.

LOOK AHEAD: Obtain the *Daphnia* and goldfish for Investigation 2.

MATERIALS (for each team of two)

- Four germinated pea or corn seeds, roots 1-2 cm long
- Petri dish
- Paper towels
- Scissors
- Garden snail
- Plastic overlay, 8½" x 11"
- Felt pen or crayon
- Flashlight

MATERIALS (for teacher)

- Shoebox
- Polyethylene plastic or aluminum foil
- Two 46-oz juice cans
- Masking tape

Preparation of Materials

Soak four pea (preferred) or corn seeds for 12-24 hours, 3 or 4 days before they are needed in class. Then transfer the seeds to a shoebox which has been lined with polyethylene plastic or aluminum foil to make it watertight. Cover the seeds with layers of wet paper towels. Keep the box of seeds at room temperature.

TEACHING TIPS

Responses to Expect: The students may need guidance in correctly positioning the four seeds. Be sure the Petri dishes are inserted in the can in the proper orientation.

Suggested forms of exercise for part B are running in place, bending to touch the toes, or deep knee bends. Students with any knee problems should *not* do deep knee bends.

The students may follow the snail too closely with the felt pen. This will cause the action of the pen to become the stimulus, rather than the light.

Practical Hints: The germination of seeds depends on many factors, including temperature and water. Determine how long it takes to germinate a pea seed with roots 1-2 cm long.

Have a student take his own pulse rate; then have his lab partner take it as a check. This will help determine if a student is taking his pulse correctly.

If flashlights are not available for the experiment with the snail, use a goose-neck desk lamp, spotlight, or high-intensity lamp. If you use any of these, a number of overlays can be placed at one time in front of the lamp.

Discussion and Review: The purpose of the experiment with the pea seeds is to provide an example to introduce the words "stimulus" and "response." Discussion of geotropism is not necessary.

The second experiment (the student counts his own pulse and breathing rate) provides a practical application for the understanding of stimulus and response. Discussion of why the two rates change would be supplementary to the lesson.

There are no right or wrong answers as to how the snails should respond. The correct answer is what the snails actually do.

Be careful that any supplementary discussions, e.g., geotropism, respiratory rate changes, do not detract from the concept of the lesson.

ENRICHMENT

1. After the pea roots are examined, the Petri dishes can be closed and put into the cans in their original position. Then give the can a 45° turn. Examine the roots 2-3 days later.
2. Demonstrate how an organism responds to a stimulus by using the *Mimosa* or Venus's flytrap plants.
3. Have a snail move along a piece of glass that is on an incline. How does it respond?

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Chapman, C.B., and J.H. Mitchell, "The Physiology of Exercise," *Scientific American,* May, 1965.

Haagen-Smit, A.J., "Smell and Taste," *Scientific American,* March, 1952.

Macey, Robert I., *Human Physiology.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968.

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McKusic, V.S., "Heart Sounds," *Scientific American,* May, 1965.

Milne, Lorus J. and Margery, *The Senses of Animals and Men.* New York: Atheneum Publishers, 1962.

von Buddenbrock, Wolfgang, *The Senses.* Ann Arbor, Mich.: University of Michigan Press, 1958.

Multi-Media Aids

Behavior in Animals and Plants: 16 mm, color, 11 min., Coronet 1011.

The Human Body: Sense Organs: 16 mm, color, 18.5 min., Coronet 1655.

Human Senses Kit: Lab-Aids 8.

Man's Senses in Action: Filmstrip, color, 40 frames, Popular Science 592.

The Mechanics of Sensation: Filmstrip, color, 40 frames, Popular Science 1533.

POSSIBLE ANSWERS

Space *a:* Student drawing. Check the orientation of the roots.

1. The roots will turn and grow downward. *Or,* the roots will grow straight ahead.

Space *b:* Student drawing. The roots should be pointing down.

2. Yes, the roots grew downward as I predicted. No, the roots grew downward and I predicted that they would grow straight ahead.

3. The plant might not survive because the roots need to grow down into the ground to get water.

TABLE NO. 1
THE PULSE RATE UNDER THREE DIFFERENT CONDITIONS

Condition	Pulse Rate Per Minute			
	1	2	3	Average
At Rest	79	78	76	77.7
Exercise	105	108	108	107
Breathing Deeply	64	64	66	64.7

4. The pulse rate increased.
5. The pulse rate decreased.
6. The exercise and deep breathing.
7. The pulse rate.
8. He might become sick if he could not adjust to a change.
9. Away from the light.
10. Light.
11. Heat and the crayon or felt pen.
12. No, there is more than one variable.

13. The movement of the snail.
14. Perhaps to move away from the drying effect of light or heat.
15. It might die from the drying effect of excessive heat or light.
16. A change that causes an organism to respond.
17. The way an organism reacts to a stimulus.
18. Living things must respond to a stimulus.

CONCEPT SUMMARY: Living things must respond to a stimulus.

BIOLOGY IDEA 4: HOMEOSTASIS, Investigation 2 (3-4 periods)

PURPOSE: Develop the concept that different stimuli can cause different responses.

DEVELOPMENT: The students will see how different chemical substances affect the heartbeat of *Daphnia* and the blood flow in a goldfish's capillary. From these data, the students will conclude that different chemical stimuli will cause different responses.

HIGHLIGHT: The learning highlight is in the three key questions in part E. As a result of his experiences with the *Daphnia* and goldfish, the student will be able to answer these questions which in turn serve as the basis for the concept summary.

LOOK AHEAD: Freeze cans or milk cartons of water needed for Investigation 3.

MATERIALS (for each team of two)

- *Daphnia*
- Dropper
- Microscope slide (preferably a depression slide)
- Cover slip
- Cotton
- Goldfish
- Petri dish
- Microscope

MATERIALS (for teacher)

The following are suggested substances.

Dropper bottles of: weak tea, weak coffee, dilute alcohol, adrenalin, nicotine solution, acetylcholine, and a tranquilizer.

Preparation of Materials

1. Have a container of clean pond or spring water ready to receive the used *Daphnia.* The students should test the chemical substances on a fresh *Daphnia* or on one that has had a chance to rinse itself out for a few hours.

2. Dilute alcohol: Make a 2% solution by adding 2 ml of ethyl alcohol to 98 ml of water.

3. Adrenalin: Purchase adrenalin that has been diluted 10,000 to 1, or make your own by adding one drop to 700 ml water.

4. Acetylcholine: Same as adrenalin.

5. Nicotine: Soak a nonfilter cigarette in 100 ml water for an hour. Filter or strain before using.

6. Tranquilizer: Each tranquilizer tablet, such as chlorpromazine, will contain either 5 mg or 25 mg of the tranquilizing substance. Dissolve each 5 mg in 25 ml water. These tablets may be purchased in small quantities (in some states) through a pharmacist if their use is noted on a piece of school stationery. A local doctor may also be a good source.

TEACHING TIPS

Responses to Expect: The normal response of the students will be to pour as much of the chemical substance on the animals as possible in anticipation of a greater response. Limit the students to no more

than two drops. This will serve as a control. Also, the one dropper bottle of each chemical substance will be sufficient for many classes.

Caution the students not to switch the droppers in the dropper bottles.

Practical Hints: Heart models can be obtained on loan (or free) from your local heart association. Merck & Co. also sells an inexpensive heart model. Use the model to supplement part A.

Show the students beforehand how to pick up a *Daphnia* with a dropper, and how to gently net and handle a goldfish. Check that the students count the heartbeat rate and not the beating of the gills in the *Daphnia.*

Assign each team of students one of the dropper bottles of chemicals. Two teams may have to share one of the bottles. Collect the bottles after the team takes its required two drops.

Discussion and Review: Review the concept learned in the first investigation–"Living things must respond to a stimulus." Direct class discussion in such a way that the students see that this investigation builds on the preceding investigation.

In discussing the questions, keep in mind that the concept is not about the circulatory system, but about body responses to various stimuli.

ENRICHMENT

1. Obtain fresh beef or lamb hearts from your local butcher.
2. Have each student type his own blood. There are a number of kits on the market that make this an easy task. Check to be sure that you can legally do this. Written parental permission is generally recommended.
3. Obtain a bottle of outdated blood from the local blood bank and use this to make stained blood slides. Scientific Products makes a stain called Hemal that is very easy to use.
4. The movie, "Hemo the Magnificent," is most appropriate at this time.

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Asimov, I., *The Human Body.* Boston: Houghton Mifflin, 1963.

Ebert, J.D., "The First Heartbeats," *Scientific American,* March, 1959.

Harvey, W., *Anatomical Studies on the Motion of the Heart and Blood.* Springfield, Ill.: Charles C. Thomas Publisher, 1931.

Miller, William H., Floyd Ratliff, and H.K. Hartline, "How Cells Receive Stimuli," *Scientific American,* September, 1961.

Scholander, P.F., "The Master Switch of Life," *Scientific American,* December, 1963.

Weggers, C.J., "The Heart," *Scientific American,* May, 1957.

Zweifach, B. W., "The Microcirculation of the Blood," *Scientific American,* January, 1959.

Multi-Media Aids

Basic Blood Typing Kit: Lab-Aids 1.

Blood Smear Kit: Lab-Aids lb.

The Blood: 16 mm, color, 16 min., Encyclopaedia Britannica 1819.

Circulatory Control: Filmstrip, color, 40 frames, Popular Science 1530.

Hemo the Magnificent: 16 mm, color, 58 min., Bell System or Modern Learning Aids.
The Human Body: Circulatory System: 16 mm, color, 13.5 min., Coronet 896.
Our Heart and Circulation: Filmstrip, color, 40 frames, Popular Science 661.
Rh Blood Typing Kit: Lab-Aids 1a.
Work of the Blood: 16 mm, color, 19 min., Encyclopaedia Britannica 1566.
The Work of the Blood: Filmstrip, color, 40 frames, Popular Science 551.
Work of the Heart: 16 mm, color, 19 min., Encyclopaedia Britannica 2559.

POSSIBLE ANSWERS

TABLE NO. 1
HEARTBEAT RATE OF DAPHNIA UNDER VARIOUS CHEMICAL CONDITIONS

Chemical	Heart Beats Per Minute			
	1	2	3	Average
Control	264	288	280	277.3
Coffee	292	301	289	294
Control	274	258	292	274.7
Chlorpromazine	184	202	214	200
Control				

1. Stimulants, e.g., coffee, tea.
2. Depressants or tranquilizers, e.g., chlorpromazine.
3. The various chemicals.
4. The changing heartbeat rate.
5. Different responses.
6. Alcohol, coffee, acetylcholine.
7. Adrenalin, nicotine.
8. Adrenalin, nicotine.
9. Alcohol, coffee, acetylcholine.
10. The different chemicals.
11. The change in the blood flow and size of the capillary.
12. Different responses.
13. The stimulus.
14. In different ways.
15. Different responses.

CONCEPT SUMMARY: Different stimuli can cause different responses.

TABLE NO. 2
CLASS DATA OF DAPHNIA HEARTBEAT RATES

Average Heartbeat Rates Per Minute Under Various Conditions		
Control	Chemical: Coffee	Chemical: Chlorpromazine
277.3	294.0	200.0
274.7	281.2	214.7
291.4	297.9	224.7
254.3	305.4	189.4
261.1	310.2	197.6
301.2	302.5	201.2
227.4	287.9	211.2
243.2	295.8	219.6
251.9	309.5	191.1
245.4	289.2	185.4
263.6	290.7	189.2
271.1	302.7	192.3
Average: 263.5	Average: 297.2	Average: 201.3

TABLE NO. 3
CAPILLARY FLOW IN A GOLDFISH'S TAIL

Chemical	Observation
Alcohol	Slowed down flow
Nicotine	Speeded up flow

TABLE NO. 4
CLASS DATA OF GOLDFISH CAPILLARY FLOW

Chemical	Observation
Alcohol	Slowed down flow
Alcohol	Slowed down flow
Alcohol	Slowed down flow
Alcohol	Slowed down flow
Alcohol	Slowed down flow
Alcohol	Stopped flow
Alcohol	Very slow flow
Nicotine	Speeded up flow
Nicotine	Speeded up flow
Nicotine	Speeded up flow
Nicotine	Speeded up flow
Nicotine	Speeded up flow
Nicotine	No change
Nicotine	Slight increase in flow

Test part A before class. The success of the experiment depends on using the proper grade of bond paper.

Part D is an optional section. The expense of the thermistor-thermometer may make it unavailable in many schools. Every effort should be made, however, to do this part.

PURPOSE: Develop the concept that each response an organism makes to a stimulus is designed to keep the organism at a constant or steady state.

DEVELOPMENT: The students will count the number of sweat glands on various parts of their bodies, using a combination of iodine and bond paper. In an optional investigation, the students measure their internal and external temperature before and after they are subjected to different environmental changes.

From these experiments the students will see that although the external environment changes, the body tries to maintain a constant internal environment.

HIGHLIGHT: The highlight comes in part D when the subject has one arm in a pan of ice water and a thermometer sticking out of his mouth. After his hand is taken out of the ice water, his skin temperature is compared to his oral temperature. The skin temperature has dropped, but the internal temperature has remained constant.

MATERIALS (for each team of two)

- Iodine solution[1]
- Cotton ball or towel
- 5 cm squares of bond paper, about six[2]
- Source of heat, e.g., heater, light bulb
- The following materials are for part D, which is optional. The experiment in part D depends on the availability of the first item.
- Thermistor-thermometer[3]
- Large pan or bucket, sufficient to immerse the arm up to the elbow
- Cans or milk cartons of ice, 5 lbs
- Stirring rod
- Laboratory thermometer
- Oral thermometer
- Paper towels

Preparation of Materials

1. To prepare iodine solution, add 1 g iodine crystals to 100 ml 95% ethyl alcohol (sufficient for one class). Or, use tincture of iodine, obtained at any drug store, and then dilute further with 95% ethyl alcohol.

2. The experiment works best with a grade of bond paper which has a high starch content. Try an erasable bond paper.

3. The thermistor-thermometer is available from Yellow Springs Instrument Co., Model 43TD with flexible glass probe.

Directions for making your own thermistor-thermometer are found in *Physiological Adaptation* by Earl Segal and Warren J. Gross (Boston: D.C. Heath, 1967, pages 102-104). Parts and directions can be ordered from Fenwal Electronics, Inc.

TEACHING TIPS

Responses to Expect: Students may indiscriminately select various parts of their body to apply the iodine and bond paper. Class discussion preceding the experiment should consider suitable areas to be tested for sweat gland activity.

Practical Hints: In testing for sweat gland activity, try to select an area where sweating occurs readily (the neck or the forehead at the hairline) and where sweating does not occur as readily (the palms or inner forearm).

To induce sweating, do not apply intense direct heat as this only creates a hot, dry spot. Cover the area with a towel or cloth before applying the heat. The ideal situation is to apply heat in a moist environment. The author has found this condition easily induced by testing an area on boys under their lower pants leg or under their shirt.

A large quantity of ice is needed for part D. Begin early to freeze cans or milk cartons of water. Ice cubes melt too fast.

The thermistor-thermometer is a device that can register skin temperature very rapidly. Caution the students *not* to hold it to the area being tested with another hand of a different temperature. Use a tongue depressor.

Discussion and Review: In parts A and B it may be necessary to collect and average the class data to get any significant results. Parts A and B are designed to complement each other. In part A, sweat gland activity should be greatest in the areas that are heated directly. In part B, sweat gland activity will be somewhat uniform because the subject is exercising his entire body.

Keep the thrust of class discussion pointed toward the concept of internal heat stabilization.

Review the concepts studied in the first two investigations, and show how they are related to the concept studied in this investigation.

ENRICHMENT

1. Prepare a paper on the physiology of the skin and its sweat glands.
2. Keep a record of body temperature every 4 hours for 24 hours and note if it varies.
3. Contrast warm-blooded and cold-blooded animals.

REFERENCES

Books and Articles

Carlson, A.J., V. Johnson, and H.M. Cavert, *The Machinery of the Body*, 5th ed. Chicago: University of Chicago Press, 1961.

Irving, Lawrence, "Adaptations to Cold," *Scientific American*, January, 1966.

Schmidt-Nielsen, K., *Animal Physiology*, 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Multi-Media Aids

Control of Body Temperature: 16 mm, black and white, 11 min., Encyclopaedia Britannica 228.

The Human Body: Muscular System: 16 mm, color, 13.5 min., Coronet 1292.

Understanding Your Body I: Filmstrip series, color, 8 filmstrips, 42 frames each, Encyclopaedia Britannica 11260.

Understanding Your Body II: Filmstrip series, color, 7 filmstrips, 42 frames each, Encyclopaedia Britannica 11580.

POSSIBLE ANSWERS

TABLE NO. 1

SWEAT GLAND COUNT IN VARIOUS AREAS OF THE BODY, HEATED AND UNHEATED

Area of Body	Number of Sweat Glands Per Square cm
Neck, heated	17
Upper arm, heated	9
Leg, unheated	0
Forehead, unheated	2

1. Forehead, underarm, neck.
2. Palm.
3. Heat.
4. Sweating.
5. To help lose excess heat.

TABLE NO. 2

SWEAT GLAND COUNT IN VARIOUS AREAS OF THE BODY AFTER EXERCISE

Area of Body	Number of Sweat Glands Per Square cm
Neck	28
Upper arm	17
Leg	19
Forehead	23

6. Not much. Sweating was not localized. The body was losing heat from all parts of the body.
7. Exercise.
8. Sweating.
9. To lose excess heat.
10. Yes. In Table 1 the data showed localized sweating because of localized heat. In Table 2, the data showed uniform sweating because of overall exercise.
11. The sweat absorbs heat from the blood.
12. Until normal body temperature is reached.
13. The body temperature.

TABLE NO. 3
EFFECT OF ICE WATER ON ORAL AND SKIN TEMPERATURE

Treatment	Temperature, ^{o}F	
	Oral	Skin
Before Immersion	98.5	85.0
After Immersion	98.7	81.5
Before Immersion		
After Immersion		

14. Yes. 2-3^{o}F.
15. No.
16. Not necessarily.
17. Maintain a constant internal temperature.
18. Body temperature.
19. Keep it at a constant state.

CONCEPT SUMMARY: Each response is made to keep the organism at a constant state.

BIOLOGY IDEA 4: HOMEOSTASIS, Investigation 4 (3-4 periods)

PURPOSE: Develop the concept that different body functions must work together to keep the body at a constant state.

DEVELOPMENT: The student notes his pulse rate, breathing rate, and the time it takes him to decolorize a basic solution before and after exercising. By analyzing the data, the student sees that the circulatory system and the respiratory system work together to keep the body at a constant state.

HIGHLIGHT: In part B, the student notes that different body functions (pulse and breathing rates) increase their responses to bring the body back to its constant state.

MATERIALS (for each team of two)

- Dropper bottle of phenol red
- Dropper bottle of an acid
- Dropper bottle of a base
- Erlenmeyer flask or beaker, 125 or 250 ml
- Stirring rod
- Soda straw
- Graduated cylinder, 100 ml

Preparation of Materials

To prepare the phenol red, an acid, and a base, see the Teachers Manual, Biology Idea 1 (Inquiry), Investigation 1.

TEACHING TIPS

Responses to Expect: Students may want to add more acid or base than is needed to cause a color change. In acid-base reactions, they should add only enough acid or base to maintain a definite color.

The students may try to blow too much air into the water. Remind them the data should reflect a normal breathing pattern.

Practical Hints: It is recommended that you use the acid and base solutions described in Biology Idea 1, Investigation 1. They are of suitable concentrations to make the reactions work well. If you use household items, such as lemon juice and ammonia, adjust the concentrations to insure that the reaction is neither too rapid nor too slow.

Use a flask, rather than a beaker or similar shaped container. The liquid will stay inside the flask more readily when swirled.

For a class demonstration, show the opposite reactions of lemon juice and ammonia to illustrate the concept of acids and bases.

Discussion and Review: The thought questions preceding part A are a transition between the first three concepts and subsequent concepts to be developed. Seek class discussion on these questions.

The last three investigations have given you an opportunity to teach about the circulatory system. In this investigation, you can introduce the subject of the respiratory system. However, each bodily system should not be taught as a separate entity. The body is a combination of many systems functioning together in a constant state.

The key questions are "17" to "24." These questions point out how the different body functions must work together.

ENRICHMENT

1. Experiment and make a table of various acids and bases.
2. Examine microscopic cross-sections of the lung to see the alveoli capillaries.
3. Make a chart showing how the heart, the blood vessels, and the lungs are related.

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Books and Articles

Butler, J. A. V., *Inside the Living Cell.* New York: John Wiley & Sons, 1962, p. 115.

Gordon, Albert S., *Blood Cell Physiology,* BSCS Pamphlet No. 8. Boston: D.C. Heath, 1963.

Griffin, D.R., *Animal Structure and Function.* New York: Holt, Rinehart & Winston, 1962.

Nourse, Alan E., and the Editors of Life, *The Body,* Life Science Library. New York: Time-Life Books, 1964.

Overmire, Thomas G., *Homeostatic Regulation,* BSCS Pamphlet No. 9. Boston: D.C. Heath, 1963.

Multi-Media Aids

Human Physiology: Filmstrip series, color, 7 filmstrips, 321 frames, SVE 570-S.

Mechanics of Breathing: Filmstrip, color, 40 frames, Popular Science 1503.

Respiration in Man: 16 mm, color, 26 min., Encyclopaedia Britannica 2772.

The Systematic Approach to Physiology: Filmstrip series, color, 8 filmstrips, Eye Gate 2-1.

POSSIBLE ANSWERS

1. It turns yellow.
2. It turns red.
3. The color alternates between yellow (acid) and red (base).
4. Whether something is acid or base.
5. Yellow (acid) and red (base).
6. A base.
7. The color changes to yellow.
8. Carbon dioxide gas.
9. Carbonic acid.
10. It increased.
11. It was a response to get rid of excess carbon dioxide.
12. It increased.
13. It was a response to carry the excess carbon dioxide out of the body.
14. Faster.
15. The body had an excess of carbon dioxide. When the carbon dioxide was exhaled into the water, it formed carbonic acid.
16. They will go back to the normal or constant state.
17. Carbon dioxide.
18. The blood.
19. Increase.
20. It is pumping faster.
21. It will flow faster because the heart is pumping faster.

22. Increase. To get rid of the carbon dioxide faster.
23. Breathing, blood flow, and heartbeat.
24. They work together to keep the body at a constant state.

CONCEPT SUMMARY: The different body functions must work together to keep the body at a constant state.

TABLE NO. 1

THE CHANGE IN A PERSON'S PULSE RATE, BREATHING RATE, AND BREATH, BEFORE AND AFTER EXERCISING

Student	Condition	Pulse Rate, Per Minute	Breathing Rate, Per Minute	Time to Decolorize Basic Solution, Seconds		
				1	2	Average
1	Rest	78.2	12	31	23	29.5
	After Exercise	106.4	31	15	17	16
2	Rest	72.7	10	25	29	27
	After Exercise	102.6	26	18	19	18.5

BIOLOGY IDEA 4: HOMEOSTASIS, Investigation 5 (3-4 periods)

PURPOSE: Develop the concept that the constant state of an organism can be upset if it is overstressed.

DEVELOPMENT: The class will be divided into two groups, smokers and nonsmokers. These groups will exercise and then determine the time it takes to return to their normal pulse and breathing rates.

HIGHLIGHT: The highlight comes when the students see the data concerning the effects of smoking. It is evident that the smokers take longer to recover from exercising.

LOOK AHEAD: Prepare starch solution for Investigation 6.

MATERIALS: None

TEACHING TIPS

Responses to Expect: The success of this investigation will depend on the technique you use to get the smokers in the class to cooperate. It is suggested that you:

a. emphasize that the experiment will be a lot of fun, without telling the students what is going to happen.

b. assure the smokers that their cooperation is needed and that no one will be reported or penalized.

The students will ask you if their pulse or breathing rate is normal as soon as they complete their first count. Assure them that everyone's rate is different and that what is considered normal is not the purpose of this experiment. However, check all the rates to assure yourself that the students are getting fairly accurate readings.

Practical Hints: The procedure for this investigation will depend on the number of smokers and nonsmokers in the class. Significant data can be obtained if there are at least eight of each. If you have at least this minimum number, it is recommended that you run the experiment on the two groups simultaneously to save time.

You will need at least two students in each group, one will be the subject and the other will take the pulse and record the data. There is no need for everyone to be the subject in this investigation.

In dividing your students into groups of twos, begin by asking all students who have never smoked a cigarette to raise their hands. Separate these students out. Then ask all students who are currently smoking on a regular basis, and those who were regular smokers to raise their hands. Separate these students into another group. You now have your two groups necessary for the experiment. The remaining students should be paired off with a smoker or a nonsmoker. These students, who did not identify themselves as either smokers or nonsmokers, have probably tried a cigarette or two but cannot be considered regular smokers.

If your class is young and the number of smokers few, you may *not* get significant data. Expect this to happen. In fact, ask your students to discuss the validity of the sample and the data.

To compensate for what may be a scarcity of smokers in one class, combine the data from several classes. Another alternative is for the students to bring in data from home from adult smokers (who smoke at least a pack a day) and nonsmokers. Although this will produce more significant data, it will not be as personal as data generated in the classroom.

Begin by having the reader learn how to find and take the subject's pulse. The subject should take his own breathing rate. Do not rush this part. Meaningful data will depend on how accurately the students take their pulse and breathing rates.

The data must represent the *time* it takes to recover and return the pulse and breathing rates to normal. The normal rate is simply one's average rate at rest. Explain to the students that they are to stop taking readings for a particular response as soon as it returns to or passes the normal rate. The latter point is significant. For instance, a student's normal (average) pulse rate may be 80 and his rate after exercising may be 100. Then, if his succeeding readings are 92, 84, 78, he is to stop at 78. (Some students may persist in taking readings until they reach 80.)

Point out, also, that the pulse rate and the breathing rate may not recover at the same rate. It may be necessary to continue taking one rate after the other has returned to normal.

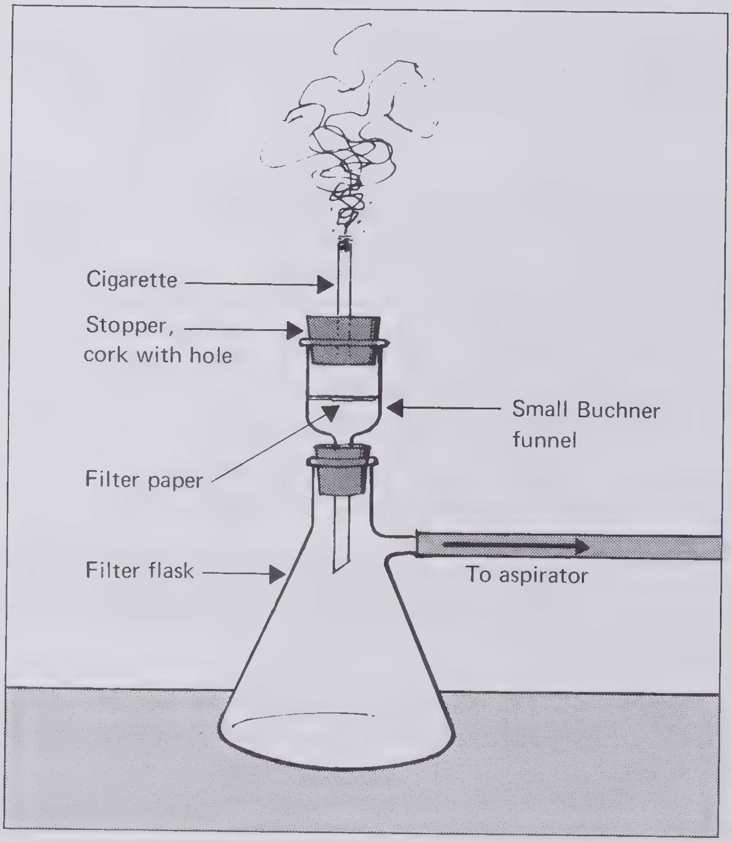
If the students have trouble understanding Table 2, you may try an alternative method. Have the students record the time at which they start to take the first reading after exercising. They then take continuous one-minute readings until the normal rate is reached. Record the final time and calculate the difference.

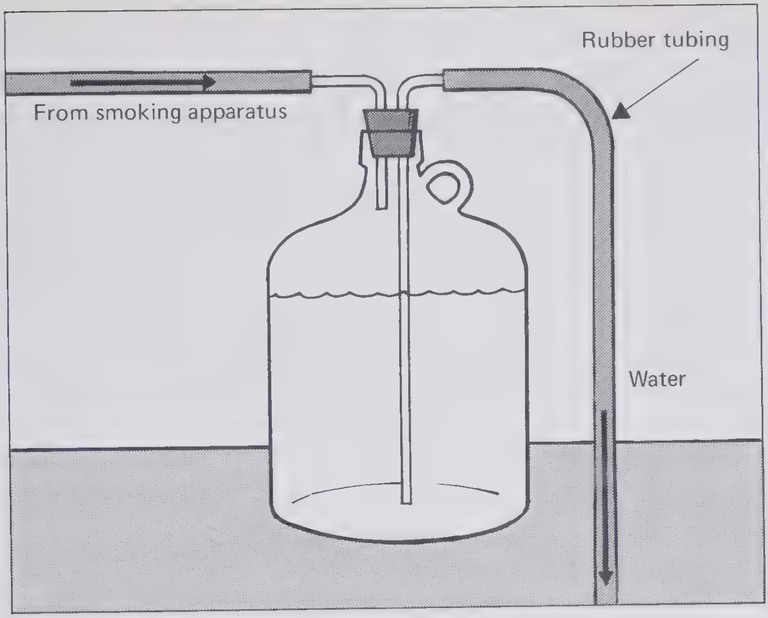
Collect the class data after the experiment is completed. Otherwise, the students may see the trend of the data and try to influence it.

Discussion and Review: The word "homeostasis" is introduced in this investigation. Use the examples of the tightrope walker and the treadmill walker to illustrate the concept. Use the question, "What happens if the balance is upset?" and the class responses as the motivating device to open the lesson.

ENRICHMENT

1. Bring in data from adult smokers and nonsmokers, and compare it to teen-age smokers and nonsmokers.
2. Trap cigarette smoke on a piece of filter paper.





3. Show various movies that are available from the American Cancer Society.

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Books and Articles

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Comroe, J.H., "The Lung," *Scientific American,* February, 1966.

Comroe, J.H., *Physiology of Respiration.* Chicago: Year Book Medical Publishers, Inc., 1965.

Fern, Wallace O., "The Mechanism of Breathing," *Scientific American,* January, 1966.

Krogh, A., *Comparative Physiology of Respiratory Mechanisms.* Philadelphia: University of Pennsylvania Press, 1959.

Multi-Media Aids

Drug Misuse and Your Health: Sound filmstrip, color, 53 frames, SVE 572-4.

The Human Body: Respiratory System: 16 mm, color, 13.5 min., Coronet 1203.

The Mechanical Smoker Kit: Instructor Publications, Inc.

Tobacco and Your Health: Sound filmstrip, color, 46 frames, SVE 572-1.

POSSIBLE ANSWERS

TABLE NO. 1

THE PULSE AND BREATHING RATE UNDER NORMAL CONDITION

Normal Condition	Trial			
	1	2	3	Average
Pulse Rate, Per Minute	76	78	74	76
Breathing Rate, Per Minute	12	11	12	11.7

TABLE NO. 2
THE TIME NEEDED FOR THE PULSE AND BREATHING RATE TO RETURN TO NORMAL AFTER EXERCISE

Exercise	Time, 2-minute Intervals						
	0	2	4	6	8	10	12
Pulse Rate, Per Minute	114	96	80	76			
Breathing Rate, Per Minute	22	18	13	12			

TABLE NO. 3
EFFECT OF EXERCISE ON PULSE AND BREATHING RATES OF SMOKERS AND NONSMOKERS

Exercise Length of Time to Return to Normal, Minutes			
Smoker		Nonsmoker	
Pulse	Breathing	Pulse	Breathing
4	2	0	0
2	2	0	0
0	2	0	0
0	4	0	0
0	0	0	0
0	2	2	2
0	4	0	2
4	0	2	2
2	4	0	2
		0	2
Total 12	20	4	10
Average 1.3	2.2	0.4	1.0

1. The lining of the tubes in the lungs is thicker and harder in smokers.
2. It is slowed down or restricted.
3. It is reduced.
4. Pump faster.
5. It increased.
6. Carbon dioxide.
7. To help get rid of the carbon dioxide.
8. To help get rid of the carbon dioxide.
9. Smokers. They may have a smaller lung capacity because of constricted tubes and broken air sacs.
10. You increase it.
11. You get rid of more of the stale air.
12. It helps him to increase his lung capacity for fresh air and force out more of the stale air.
13. Smokers. They have a smaller lung capacity.
14. Smokers. The heart has to beat faster to make up for the reduced lung capacity.
15. Smokers. It takes longer to make up for the reduced lung capacity.
16. It will be upset.

CONCEPT SUMMARY: If the body's constant state is overstressed, it will be upset.

BIOLOGY IDEA 4: HOMEOSTASIS, Investigation 6 (3-5 periods)

PURPOSE: Develop the concept that each body process operates best at its particular constant state.

DEVELOPMENT: The students will test the digestive action of saliva on a starch solution under different concentrations and different temperatures. From these experiments, the students will find that digestion takes place more efficiently when the saliva is at an optimum concentration and temperature.

HIGHLIGHT: The experiments that make use of the saliva are individual highlights in themselves. The data that result from each experiment help the student to develop the concept.

MATERIALS (for each team of two)

- Prepared starch solution, 30 ml[1]
- Saliva, 30 ml
- Dropper bottle of Lugol's solution[2]
- Benedict's solution, 100 ml[3]
- Test tubes, 4
- Beaker, 250 ml
- Test tube holder
- Burner, alcohol or Bunsen
- Cracker or bread
- Graduated cylinder, 10 ml or 25 ml
- Labeling tape or marking pen
- Crushed ice or refrigerator
- Hot water

Preparation of Materials

1. To prepare starch solution, make a paste of 2 g of starch in 2-3 ml of water. Slowly add 1 liter of hot water, stirring continuously. Bring the mixture to a boil and then store in a covered container in a refrigerator. (This will slow down the digestion of the starch to sugar by microorganisms.) After 2-3 days, decant the clear solution and test a small part with iodine. It should give a strong test for starch.

2. You can make your own Lugol's solution by dissolving 6 g of KI in 100 ml water. Then add 4 g iodine (I_2) crystals.

3. Purchase Benedict's solution from a supply house, or make your own. Dissolve 173 g sodium citrate and 100 g Na_2CO_3 in 800 ml of hot distilled water. Filter and dilute to 850 ml. Dissolve 17.3 g $CuSO_4 \cdot 5H_2O$ in 100 ml water. Pour the latter solution into the former, stir, and add enough water to make a total of 1 liter.

TEACHING TIPS

Responses to Expect: The students may rebel at the thought of collecting their own saliva. If saliva is thought of as a normal body fluid, it can be collected with a positive attitude.

Many students expect clear-cut chemical reactions. This is not the case in the color reaction from a Benedict's test. Although a quantitative determination will not be possible, alert the students to observe different amounts of orange present.

Practical Hints: Saliva can be collected very easily by having the student chew on a rubber band or a small piece of sugarless gum.

Although it is more expensive, glucose test tape can also be used to test for the presence of sugar. It is sold under various trade names, (e.g., Clinistix) and is used by doctors to test for the presence of sugar in urine. It can be purchased from any medical supply house or Scientific Products.

Each of the three experiments should be done separately. This will reduce the number of test tubes needed by a team at any one time.

One container of crushed ice and one container of hot water will be sufficient for the entire class. Have students label their own tubes for identification.

Discussion and Review: Since saliva varies in potency from person to person, it may be necessary to use different amounts of starch or saliva. The experimental data may also be affected if saliva is collected from students who have just eaten candy or chewed gum. They should rinse their mouths first.

Discuss the questions that accompany each experiment before proceeding to the next experiment.

ENRICHMENT

1. Study the effect of the *p*H of saliva on the digestion of starch.
2. Do a paper on ulcers.

REFERENCES

Books and Articles

Beaumont, William, *Experiments and Observations on the Gastric Juices and the Physiology of Digestion* (1833). New York: Dover Publications, Inc., 1959, pp. 127-129.

Boyd-Orr, J., "The Food Problem," *Scientific American,* August, 1950.

Davenport, H.W., *The Physiology of the Digestive Tract,* 2nd ed. Chicago: Year Book Medical Publishers, Inc., 1966.

Frieden, E., "The Enzyme-Substrate Complex," *Scientific American,* August, 1959.

Mayer, S., "Appetite and Obesity," *Scientific American,* November, 1956.

Pfeiffer, John E., "Enzymes," *Scientific American,* December, 1948.

Multi-Media Aids

Alcohol and Your Health: Sound filmstrip, color, 44 frames, SVE 572-2.

The Digestive System: 16 mm, color, 17 min., Encyclopaedia Britannica 2245.

Enzymes–The Spark Plugs of Life: Filmstrip, color, 40 frames, Popular Science 575.

The Human Body: Chemistry of Digestion: 16 mm, color, 16 min., Coronet 1653.

The Human Body: Digestive System: 16 mm, color, 13.5 min., Coronet 895.

The Human Body: Nutrition and Metabolism: 16 mm, color, 13.5 min., Coronet 1289.

Man's Digestive System: Filmstrip, color, 40 frames, Popular Science 1512.

Sugar Metabolism: Filmstrip, color, 40 frames, Popular Science 1548.

TABLE NO. 1
TESTING STARCH AND SALIVA FOR THE PRESENCE OF STARCH AND SUGAR

Substance Tested	Presence of	
	Starch	Sugar
Starch (with iodine)	Yes	No
Starch (with Benedict's)	No	No
Saliva (with Benedict's)	No	No

1. Sugar is not present in starch or in saliva.
2. It becomes clear.
3. Yes.
4. The saliva might have changed the starch to sugar.
5. It becomes sweet.
6. Test for sugar with Benedict's solution.
7. Saliva changes starch to sugar.
8. Changes them to sugar.

TABLE NO. 2
THE EFFECT OF DIFFERENT CONCENTRATION OF ENZYMES ON THE DIGESTION OF STARCH

Condition of Tube	Presence of Sugar
(1) Starch	No
(2) Starch, 5 ml Saliva	Yes
(3) Starch, 2 ml Saliva 3 ml Water	Some
(4) Starch, 0.5 ml Saliva 4.5 ml Water	Very little

9. Tube 1.
10. No. There was no saliva present to change it to sugar.
11. Most in tube 2; some in tube 3; very little in tube 4.
12. Tube 2 had the highest concentration of saliva. Tube 4 had the lowest concentration of saliva.
13. Food could not be digested.

TABLE NO. 3
THE EFFECT OF DIFFERENT TEMPERATURES ON THE DIGESTIVE ACTION OF ENZYMES ON STARCH

Condition of Tube	Presence of Sugar
(1) Starch and Saliva in Ice	No
(2) Starch and Saliva in Hot Water	No (if hot enough to destroy enzyme)
(3) Starch and Saliva at Room Temperature	Yes
(4) Starch at Room Temperature	No

14. Tube 4.
15. Tube 3.
16. Tube 1 was too cold for the enzyme to work; tube 2 was too hot for the enzyme to work.
17. A moderate temperature, not too hot and not too cold.
18. Enzymes must have the proper temperature to function.
19. Optimum.
20. Balance point.

CONCEPT SUMMARY: Each body function operates best at its particular constant state.

Prepare hard-boiled eggs and a yeast culture the day before you start this investigation.

PURPOSE: Develop the concept that membranes help to regulate the homeostatic balance in an organism.

DEVELOPMENT: The students will see the osmotic action of various substances through an egg's membrane, and the destruction of a yeast cell's ability to regulate the flow of materials into and out of itself.

From these experiments, the students will find that the cellular membrane is capable of regulating the passage of materials into and out of a cell.

HIGHLIGHT: The time-tested use of egg membrane and a soda straw to demonstrate osmosis highlights the concept of membrane permeability.

LOOK AHEAD: Order the day-old cockerels for Investigation 8, and multi-media aids for Investigation 9.

MATERIALS (for each team of two)

- Index card, 3" x 5", two
- Cellophane tape
- Beaker, 250 ml
- Clear plastic straws, two
- Egg membrane or dialysis tubing
- Thread
- Sugar solution[1]
- Corn or maple syrup[2]
- Molasses[3]
- Dropper with drawn out tip, or smaller straw
- Yeast culture[4]
- Microscope slide
- Cover slip
- Microscope
- Test tubes, two
- Test tube holder
- Burner
- Dropper bottle of Congo red dye[5]

Preparation of Materials

1. Add enough water to 10 g sugar to make 100 ml of sugar solution.
2. Dilute corn or maple syrup with an equal part of water.
3. Dilute molasses with an equal part of water.
4. Add 1 package dry yeast and 100 g brown sugar to 500 ml water. Stir and store overnight in a warm place.
5. Add a pinch of Congo red dye to 100 ml water to get a medium-colored stain.

TEACHING TIPS

Responses to Expect: The egg membranes are very delicate. If your students find it too difficult to work with egg membranes, substitute dialysis tubing.

The addition of the various liquids to the straw requires patience and moderate skill. Let the students practice with water first.

Practical Hints: To reduce the number of beakers needed, place two groups of straws over one beaker. Any kind of a container, such as milk cartons, jars, and bottles, can be used instead of beakers. To further reduce the number of beakers needed, have each team of two students prepare only one straw. Then combine the efforts of four teams on one card.

If you do not have an IIS equipment package, you can obtain droppers with drawn out tips from Scientific Products as DiSPo pipets.

Discussion and Review: The student is not expected to understand the concepts of diffusion, osmosis, or active transport. However, he should see that the cell membrane is differentially permeable. If the cell membrane is destroyed, this ability to regulate is lost.

Supplement this lesson with a discussion of: (1) diffusion, osmosis, and active transport; (2) the excretory system; and (3) the importance of water balance in the body.

ENRICHMENT

1. Prepare a paper on the exchange of materials and liquids in the kidney.
2. Prepare a model of osmosis using a cored carrot filled with molasses and a glass tube attached to its top.
3. Observe the plasmolysis of an *Elodea* cell under the microscope when subjected to a 5% saline solution.

REFERENCES

Books and Articles

Merrill, J.P., "The Artificial Kidney," *Scientific American,* July, 1961.

Pitts, R.F., *Physiology of the Kidney and Body Fluids.* Chicago: Year Book Medical Publishers, Inc., 1963.

Robertson, David J., "The Membrane of the Living Cell," *Scientific American,* April, 1962.

Soloman, A.K., "Pores in the Cell Membrane," *Scientific American,* December, 1960.

Soloman, A.K., "Pumps in the Living Membrane," *Scientific American,* August, 1962.

Swanson, Carl P., *The Cell,* 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Multi-Media Aids

The Human Body: Excretory System: 16 mm, color, 13.5 min., Coronet 1206.

Osmosis and Diffusion Kit: Lab-Aids 22.

Your Kidneys–Living Filters: Filmstrip, color, 40 frames, Popular Science 1505.

POSSIBLE ANSWERS

TABLE NO. 1
OBSERVATIONS ON THE PASSAGE OF DIFFERENT SUBSTANCES THROUGH A MEMBRANE

Contents of Straw	Observation
Water	No change
Sugar	Slight change in level of substance
Corn Syrup	Moderate change in level of substance
Molasses	Great change in level of substance

1. The straw containing water.
2. Yes. The control.
3. The other three straws showed changes.
4. No, or very slight. (This indicates that not much sugar leaked through the membrane.)
5. Water passed through the membrane.
6. Regulate what can pass through it.

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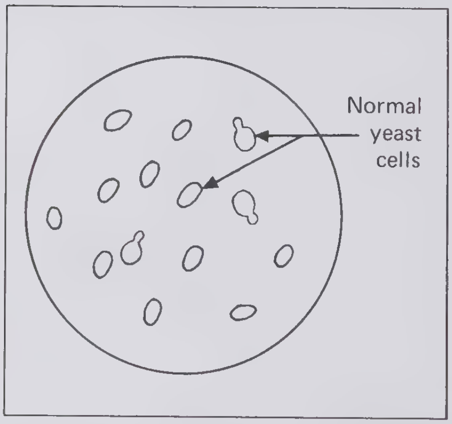

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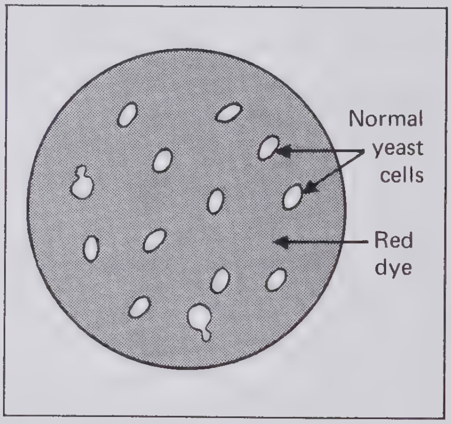

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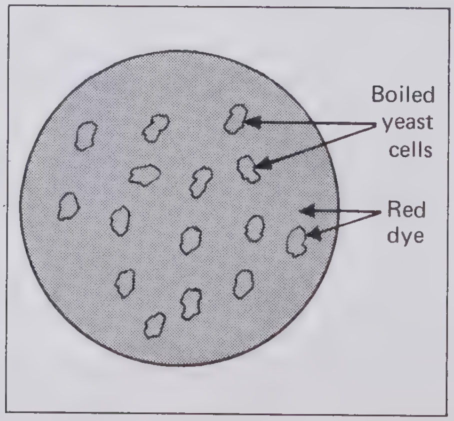


7. Outside.
8. Inside.
9. Boiling killed the yeast cells.
10. Yeast cell membranes were destroyed when the yeast was boiled.
11. To regulate passage of materials.
12. The living cell membrane was able to regulate or keep the red dye out. The destroyed cell membrane was not able to keep the red dye out.
13. Cell membrane.
14. The cell membrane.

CONCEPT SUMMARY: Membranes help the body to regulate its constant state.

If possible, start the chick experiment on a Monday and the seed experiment on a Tuesday. Make the final readings of both on a Friday.

PURPOSE: Develop the concept that hormones help the body regulate its constant state.

DEVELOPMENT: The students will apply testosterone to a group of day-old cockerels, and an auxin to a group of germinating seeds. The results of the experiments will show that hormones affect the growth of an organism.

HIGHLIGHT: The dramatic growth of the chicks' combs after treatment with testosterone will definitely be the special learning feature of this investigation.

LOOK AHEAD: Three- to four-week-old bean plants are needed for Idea 5, Investigation 2. Read ahead.

MATERIALS (for each team of two or four)

- Day-old cockerels, two[1]
- Testosterone ointment[2]
- Ruler
- Scissors
- Petri dish
- Paper towels
- Pea seeds, five
- Oat seeds, five
- Hormone, indoleacetic acid, 20 ml[3]
- Graduated cylinder

MATERIALS (for teacher)

- Chick brooder[4]
- Chick mash

Preparation of Materials

1. For day-old cockerels, check the Yellow Pages in your phone book under "poultry," "eggs," or "hatcheries." As soon as the eggs are hatched, they are sexed. The cockerels are usually discarded or can be purchased for about 5¢ each.

2. Testosterone propionate in oil or aqueous solution can be obtained from a biological supply house or a local druggist. In addition, obtain some ointment base or cold cream from the local druggist. Mix 10 ml of the testosterone in enough ointment base or cold cream to fill a 50-ml beaker.

3. Indoleacetic acid can be obtained from any biological supply house or from any organic chemical supplier. Dissolve 0.1 g in 2-3 ml of ethyl alcohol. Add to enough water to make a liter of solution. Then heat gently to drive off the alcohol.

4. To make a chick brooder, cover the bottom of a cardboard box with wood shavings or sawdust. Suspend a 40-60 watt bulb above the box to provide heat. Provide a container for water and another for chick mash. Change the water daily.

TEACHING TIPS

Responses to Expect: Give each group of students a shoebox lined with towels to hold the chicks. This will reduce the amount of squealing in the class.

The students will probably respond with the concept that hormones only control growth. The two experiments in this investigation certainly demonstrate that concept. Therefore, it will be necessary for you to tell the students that growth is only one of the factors controlled by hormones.

Practical Hints: Buy only enough chicks for one class. All succeeding classes can use the same chicks. However, they should be marked so that each student team observes the same two chicks every day. Pigeon leg bands, available at feed or pet stores, can be used. Otherwise, colored felt pens can be used to lightly mark the feathers.

When you buy your chick mash, find out at the feed store if anyone wants the chicks at the end of the experiment. Invariably, someone does and this is better than giving them out to the students.

If possible, soak the seeds one day before the class uses them. Soak the control seeds in water and the experimental seeds in the plant hormone.

Add more water or hormone if the seeds start to dry out. The 20 ml called for in the directions should be enough, provided the seeds are kept in a warm, dark place.

Discussion and Review: Supplement this investigation with a discussion of glands and hormones. You may also want to talk about production of hormones in plants and how plant hormones affect geotropism.

In discussing part C, emphasize how hormonal regulation depends on the amount of hormone secreted.

ENRICHMENT

1. Grow a flat of grasses and broadleaf weeds. Spray with 2-4 D to show how hormones can upset the growth metabolism of a plant.

2. Do a paper on a disease caused by a hormone imbalance.

3. Grow some dwarf and regular peas. Spray the dwarf pea seedling with gibberellic acid, a plant hormone, to show how a plant hormone can accelerate growth.

REFERENCES

Books and Articles

Davidson, E.H., "Hormones and Genes," *Scientific American*, June, 1965.

Levine, R., and M.S. Goldstein, "The Action of Insulin," *Scientific American*, May, 1955.

Tepperman, J., *Metabolic and Endocrine Physiology*. Chicago: Year Book Medical Publishers, Inc., 1963.

Tustin, A., "Feedback," *Scientific American*, September, 1952.

Wilkins, L., "The Thyroid Gland," *Scientific American*, March, 1960.

Zuckerman, S., "Hormones," *Scientific American*, March, 1957.

Multi-Media Aids

Biology–Disorders in Humans: Filmstrip series, 6 filmstrips, color, 50 frames each, Jam Handy 1380.
How Hormones Control the Body: Filmstrip, color, 40 frames, Popular Science 557.

POSSIBLE ANSWERS

1. The germinating seeds given plant hormones would grow faster or larger than the seeds not given plant hormones.

TABLE NO. **1**

THE EFFECT OF A PLANT HORMONE ON THE LENGTH OF PEA AND OAT ROOTS

Seeds	Length of Roots Under Two Different Treatments, mm											
	Water						Hormone					
	1	2	3	4	5	Ave.	1	2	3	4	5	Ave.
Peas	15	17	14	14	11	14.2	17	19	17	20	16	17.8
Oats	9	7	5	6	9	7.2	8	10	11	9	12	10.0

2. Yes. The roots on the seeds treated with the hormone were longer.
3. The plant hormone.
4. It will grow larger or faster.

TABLE NO. **2**

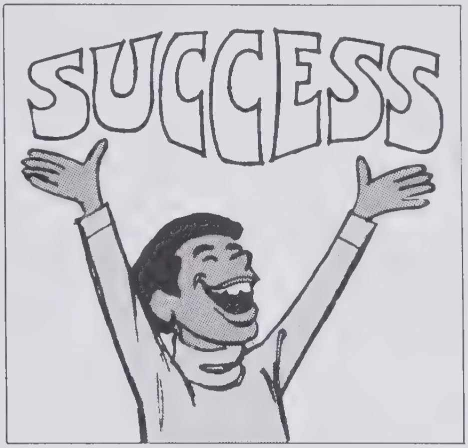
THE SIZE OF THE COMB ON TWO ONE-DAY OLD COCKERELS, ONE TREATED AND ONE UNTREATED WITH TESTOSTERONE

Day	Treated			Untreated		
	Height, mm	Length, mm	Height X Length mm	Height, mm	Length, mm	Height X Length mm
1	5	9	45	5	9	45
2	6	12	72	6	11	66
3	8	15	120	6	12	72
4	8	19	152	7	14	98
5	9	22	198	7	16	112

5. The control.
6. Yes. The comb treated with hormone grew faster.

7. Treating the comb with hormone.
8. Membrane.
9. Hormones.
10. To regulate its internal constant state.

CONCEPT SUMMARY: Hormones help the body regulate its internal constant state.



BIOLOGY IDEA 4: HOMEOSTASIS, Investigation 9 (2-3 periods)

PURPOSE: Develop the concept that the nervous system coordinates all of the body systems necessary to maintain a constant state.

DEVELOPMENT: The students will read about and discuss drug abuse. As a result of this lesson, the students will learn that drugs can upset the nervous system, causing a homeostatic imbalance.

HIGHLIGHT: The topic of drug abuse is a socially relevant subject with today's teen-agers. It comes with its own built-in motivation and highlight.

MATERIALS: None. However, use as many of the multi-media aids to supplement the lesson as possible.

TEACHING TIPS

Responses to Expect: Expect a bimodal response to the subject of drug abuse. The nonusers will be sympathetic to whatever you have to say. The users may not be hostile, but some may challenge the adult values which permit smoking, alcohol, and drugs to be consumed in great quantities. By all means, accept the fact that drug abuse is a problem people of all ages must face.

Many of the users, however, will remain passive. The drug abuser is usually in the throes of a deep psychological problem.

Values cannot be told, taught, or given. They must evolve out of a person's own convictions. Guide the students to reach their values; don't force them.

Practical Hints: Here are six concrete suggestions:

a. *Know Your Subject:* A teacher can become very defensive about the subject of drugs, especially when he discovers that many of the students know more than he does. Greater knowledge on the part of the students may not necessarily be correct. There is a language peculiar to the drug cult that sometimes gives one an illusion of knowledge. It would be worthwhile to learn the language or jargon. If you do so, the students will be more likely to listen to you.

Much of the controversy over drugs, in particular marijuana, results from overinterpretation or misrepresentation of the available data. Insist that the students provide evidence for any beliefs they may have regarding the benefits of drugs.

There is no substitute for the knowledgeable teacher who can supply facts more readily than pious preaching. From the list of references, be sure to read *The Drug Scene* and *Students and Drug Abuse.*

In addition, make full use of local law enforcement and medical societies. They can frequently furnish guest speakers or consultants.

b. *Keep Lines of Communication Open:* Avoid making moralistic and judgmental speeches. Listen to your students. Young people are anxious for help, but they will turn you off if you become autocratic. Each person must arrive at his own set of values.

c. *Avoid Scare Techniques:* Isolated sensational incidents should not be offered as typical of what may happen to all drug abusers. For every scare account, the students will be able to cite many direct experiences to contradict them.

d. *Avoid Stereotyping People:* Do not categorize all drug users as people with long hair and eccentric dress. Students can easily detect an air of distrust, thus destroying any climate of trust and confidence essential for open communication.

e. *Use Your Student Resources:* Student prepared discussions, reports, charts, and displays can frequently be more effective than any lecture the teacher may prepare. Young people are most responsive to the morals and values of their own group.

The teacher should provide the ground rule that all arguments must be supported by evidence. Teen-agers frequently are quite adept at masking their uncertain arguments behind a facade of drug language and cult cliches. The students will be forced to test the validity of their beliefs if they are made to present a report of their own.

f. *Stress Alternatives to Drugs:* The teen-ager searching for his place in the sun is susceptible to the slightest whim, fad, or fancy. In addition, he is easily impressionable and desperately in need of acceptance. If the attributes of drugs are sufficiently appealing, he will try them. But if a "turned on" teacher can convince students that *they* can be turned on by being involved in civic activities of interest to them, programs for the disadvantaged, or volunteer work in a church, he will be much more effective than the teacher who continuously preaches the negative aspects of drugs. As the kids say, "get turned on with sunshine."

Discussion and Review: This investigation should be used as a springboard for further discussion. It should be supplemented with mixed-media presentations, student discussions, and community resource personnel.

ENRICHMENT

1. There are presently no statistical controls to measure the extent of drug usage. Discuss what aspects of drug use make collection of such data difficult.

2. People who started using drugs have given such reasons as: curiosity; going along with the gang; afraid of being left out; desired to; no good reason for not doing so, so decided to try it; forced to do so by peers; medical reasons; and for kicks. Discuss the validity of the reasons.

3. Some people have suggested that there is such a thing as a "drug type." Discuss the validity of this statement.

4. Many drug advocates argue that they get "turned on" by drugs. Make a list of other ways people get turned on in a more positive manner, such as by one's work; by financial gain; by one's religious belief; by being popular; by being in love; and by being active in school and civic activities.

5. There are dozens of additional suggestions for enrichment in the book, *The Drug Scene.*

REFERENCES

Books and Articles

Asimov, Isaac, *The Human Brain.* Boston: Houghton Mifflin, 1963.

Benziger, T. H., "The Human Thermostat," *Scientific American,* January, 1961.

Grey, W. W., "The Electrical Activity of the Brain," *Scientific American,* June, 1954.

Loewenstein, W. R., "Biological Transducers," *Scientific American,* August, 1960.

Marrazzi, A. S., "Messengers of the Nervous System," *Scientific American,* February, 1957.

Way, Walter L., *The Drug Scene.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970.

Wilson J., and the Editors of Life, *The Mind.* New York: Life Science Library, Time-Life Books, 1964.

Multi-Media Aids

Drug Abuse: Filmstrip series, color, 3 filmstrips, 51 frames each, Encyclopaedia Britannica, 11270.

Drug Misuse and Your Health: Sound filmstrip, color, 53 frames, SVE 572-4.

Drugs and the Nervous System: 16 mm, color, 16 min., Churchill.

Exploring the Human Nervous System: 16 mm, color, 23 min., Churchill.

Fundamentals of the Nervous System: 16 mm, color, 17 min., Encyclopaedia Britannica 1554.

Hooked: 16 mm, black and white, 20 min., Churchill.

The Human Body: The Brain: 16 mm, color, 16 min., Coronet 1742.

The Human Body: Nervous System: 16 mm, color, 13.5 min., Coronet 894.

The Nervous System: Filmstrip, color, 40 frames, Popular Science 544.

POSSIBLE ANSWERS

1. *Arguments For:*
   a. To heighten one's sense of awareness.
   b. To think at a deeper level.
   c. To become more effective in coping with the environment and in solving personal problems.
   d. To experience a pleasurable sensation.
2. *Arguments Against:*
   a. It is against the law.
   b. It will lead to a withdrawal from society.
   c. It helps to support organized crime.
   d. It leads to harmful psychological and physical effects.
   e. It develops a tendency to forego responsibility.
   f. It may lead to the production of deformed children.
3. Nervous system.
4. Nervous system.
5. Nervous system.

CONCEPT SUMMARY: The nervous system coordinates the various life functions necessary to maintain homeostasis.

BIOLOGY IDEA 4: HOMEOSTASIS, Investigation 10 (1-2 periods)

PURPOSE: Develop the concept that life is a continuous struggle to keep various processes at a constant state.

DEVELOPMENT: The students will play a card game which summarizes much of what they have studied in the previous investigations.

The card game illustrates how various parts of the body undergo a constant homeostatic interaction of stimulus and response, and provides a summary of Idea 4.

HIGHLIGHT: The enjoyment of the game, *Homeostasis,* helps to motivate the learner in his understanding of Idea 4.

MATERIALS (for each team of four)

Homeostasis game

Preparation of Materials

If you do not have an IIS equipment package, you and your students may prepare your own sets of the game, as follows:

1. Make two copies each of the two pages that have "Homeostasis" spelled across the top of the pages. (See pp. 180-184 of this Teachers Manual.)

2. Make six copies each of the three pages that have the individual cards printed on them.

3. Glue the pages with the cards on them on file folders.

4. Cut out the individual cards.

5. Assemble a deck of 114 cards according to the scheme printed on page 211 of the student edition. Note: You will have some extra calorie cards. Do *not* include these in the decks used by the students.

TEACHING TIPS

Responses to Expect: The classroom environment will be noisy. Hopefully, the students will not only enjoy themselves, but also find the game to be an educational experience.

Practical Hints: The game, *Homeostasis,* can be used at other times in the course, especially when there is a 20-minute lull in the period.

If three play, an additional set of the two pages with the word, "Homeostasis," printed across the top will have to be copied.

Discussion and Review: All of the earlier concepts in this Idea should be reviewed before playing the game.

Since the game probably will be played more than once and on more than one day, the 12 individual upsetting stimuli and response situations in the game should be discussed at an appropriate break. For instance, the students may need "insulin" or "obesity" redefined. The significance and meaning of "security" will certainly merit discussion.

Inasmuch as this is the final activity in Idea 4, the students should be asked to summarize the basic idea which encompasses all of the concepts they have been studying, and to enter this idea in the IDEA Summary.

ENRICHMENT

Write a paper on a homeostatic mechanism; e.g., the balance of water, the temperature response of the hypothalamus, the hunger response, or the growth rate of a plant.

REFERENCES

Books and Articles

Brookhaven Symposia in Biology, *Homeostatic Mechanisms No. 10.* Upton, N. Y.: Brookhaven National Laboratory, 1957.

Langley, L. L., *Homeostasis.* New York: Reinhold Publishing Corp., 1965.

Multi-Media Aids

Homeostatic Regulation: Filmstrip, color, 40 frames, Popular Science 1535.

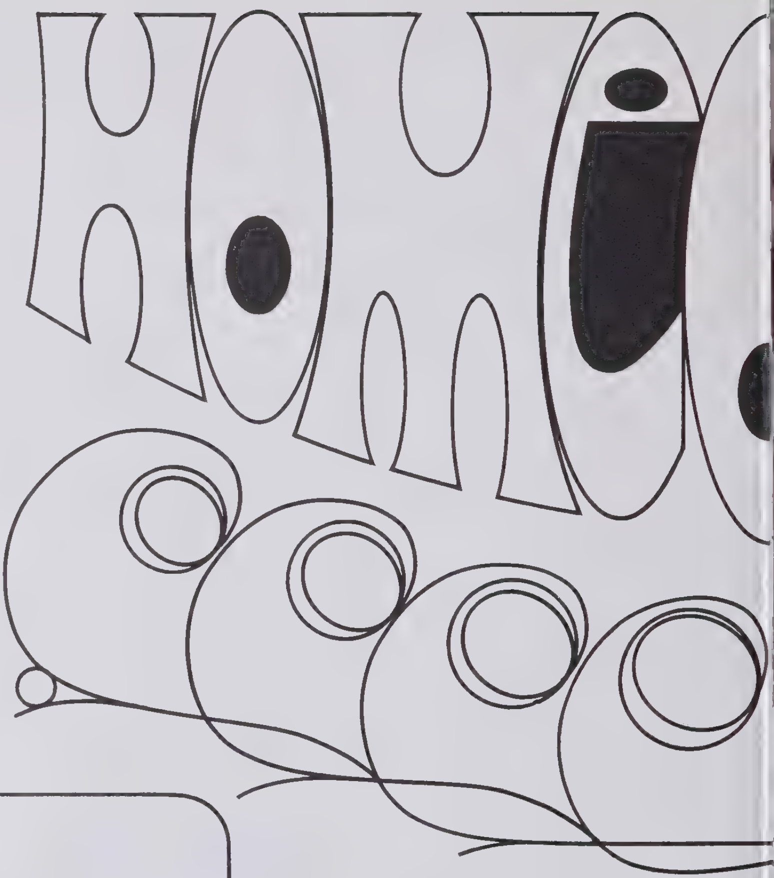
Plant Tropisms and Other Movements: 16 mm, color, 11 min., Coronet 1048.

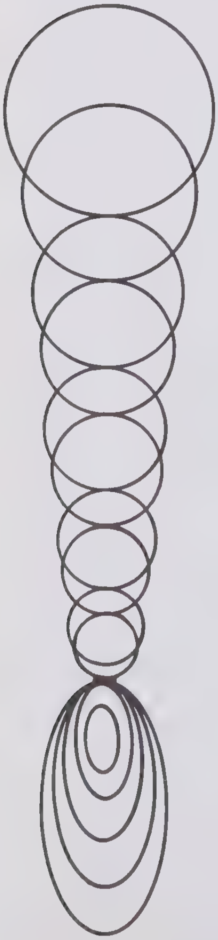
IDEA SUMMARY: Life is a continuous struggle to keep various processes at a constant state.

UPSET WITH ULCERS
RESPOND WITH ANTIACID

STOMACH

NEED EXACTLY 400
CALORIES TO WIN





UPSET WITH DIABETES
RESPOND WITH INSULIN

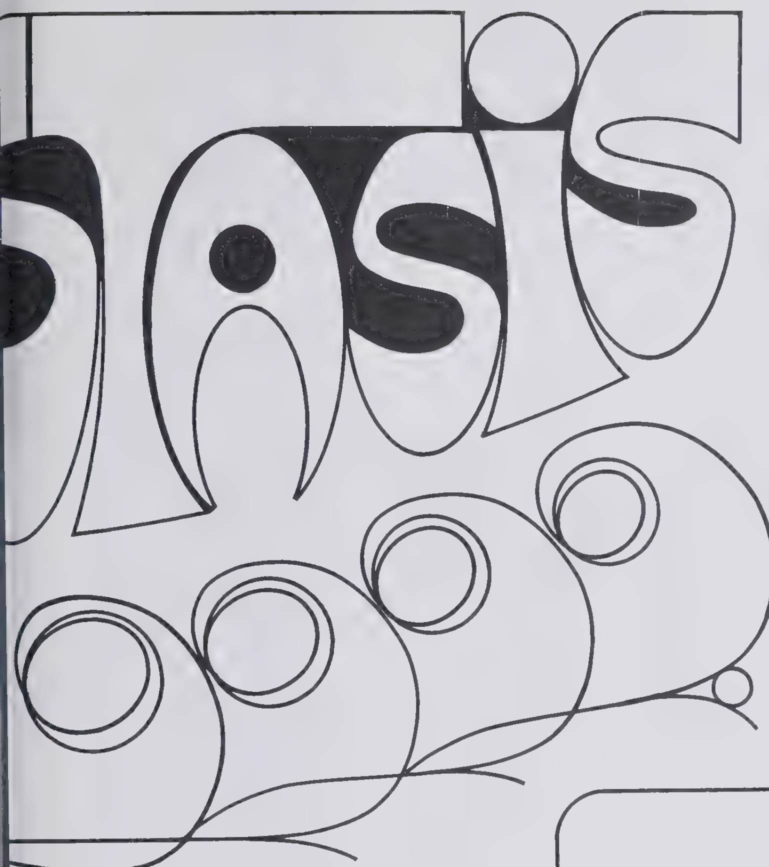
SMALL intestine

NEED EXACTLY 400
CALORIES TO WIN

UPSET WITH THE RUNS
RESPOND WITH CAMP-OUT

LARGE intestine

NEED EXACTLY 400
CALORIES TO WIN



UPSET WITH BUM TRIP
RESPOND WITH SECURITY

NERVOUS SYSTEM

NEED EXACTLY 400
CALORIES TO WIN

UPSET WITH OBESITY
RESPOND WITH DIET

HEART

NEED EXACTLY 400
CALORIES TO WIN

UPSET WITH LUNG CANCER
RESPOND WITH STOP SMOKING

LUNG

NEED EXACTLY 400
CALORIES TO WIN

Ulcer

You *worry too much.*

Place above stomach to stop.

Respond with an *anti-acid tablet* card to continue.

Obesity

You eat too much, Fatso. It's straining the heart.

Place above a heart card to stop.

Respond with a *diet* card to continue.

Lung Cancer

You've been smoking too much.

Place above a lung card to stop.

Respond with a *stop smoking* card to continue.

Diabetes

You have a hereditary disease.

Place above a small intestine card to stop.

Respond with an *in-sulin hormone* card to continue.

The Runs

You have a bacterial infection. Run to the bathroom and camp there.

Place above a large intestine card to stop.

Respond with a *camp-out* card to continue.

Bum Trip

Another bad freak out.

Place above a nervous system card to stop.

Respond with a *security* card to continue.

Anti-Acid

This tablet will re-store the balance upset by an *ulcer.*

Place over an *ulcer* card before con-tinuing.

Security

You are now sure of yourself. No need to escape into un-reality.

This feeling will restore the balance upset by a *bum trip.*

Place over a *bum trip* card before continuing.

INSULIN

This hormone will restore the balance upset by *diabetes*.

Place over a *diabetes* card before continuing.

STOP SMOKING

This method may restore the balance upset by *lung cancer*.

Place over a *lung cancer* card before continuing.

CAMP-OUT

You are now free to leave the bathroom.

This method will restore the balance upset by *the runs*.

Place over *the runs* card before continuing.

DIET

Hi skinny.

This method will restore the balance upset by *obesity*.

Place over an *obesity* card before continuing.

300 CALORIES

100 CALORIES

100 CALORIES

100 CALORIES

200 CALORIES

200 CALORIES

200 CALORIES

200 CALORIES

Idea 5
Ecology

The final Idea in the IIS biology program is based on the word everyone is talking about today, ecology. The two most common misconceptions about ecology are that it is a study of nature or a dangerous condition of our environment brought on by pollution. Ecology, however, is really the study of biological interdependence. In Idea 5, the classical definition and the popular usage of ecology are blended together.

When the student finishes, he will have discovered the IDEA Summary that:

ALL LIVING THINGS CONSTANTLY NEED ENERGY AS THEY INTERACT WITH THEIR ENVIRONMENT.

Idea 5 has as its major theme, mutual dependence. This is the relationship of all living things to each other and to their environment. Since energy is sought after in most mutually dependent relationships, the first four investigations develop the concept of energy synthesis. Here we see the ecological relationship of plants to the environment. In Investigations 5 and 6, we examine energy breakdown or respiration. Using the concepts of energy synthesis and breakdown, the next three investigations develop the concepts of food or energy relationships in various ecosystems. And finally, in the last investigation, the students see that pollution can upset an ecological system that may be in homeostatic balance.

BIOLOGY: IDEA FIVE (ECOLOGY)

All Living Things Constantly Need Energy as They Interact with Their Environment

INVESTIGATION	*CONCEPT DEVELOPED*	*NATURE OF THE ACTIVITY*
1. YOU EAT NEARLY A TON OF FOOD	All living things constantly need energy.	Burning nuts; measuring calories
2. A STORY THAT'S FULL OF HOLES	Plants need carbon dioxide and light to make starch.	Finding stomates; testing leaves for starch
3. THE IMPORTANCE OF BEING GREEN	Plants need chlorophyll to maintain life.	Chromatography of chlorophyll
4. YOUR LIFE DEPENDS ON PLANTS	Plants produce oxygen.	Measuring oxygen production
5. BUBBLE, BUBBLE, TOIL—NO TROUBLE	Carbon dioxide is released when food is broken down for energy.	Respiration of yeast
6. LOOK, THERE IN THE FOOD!	Living things need oxygen to release energy if life is to continue.	Respiration of pea seeds
7. A CITY FULL OF NATURE	A community is an organized group of populations living in mutual dependence (and is dependent upon energy for survival).	Ecological survey
8. A MOLD CAN SAVE YOUR LIFE	All living things compete with other living things for the available energy in a food web.	Bacterial competition
9. IT'S A SMALL WORLD	A succession of organisms can be observed in a community until a climax is established.	Succession of microorganisms
10. BEAUTIFUL DOWNTOWN BURBANK	Destructive influences can upset a climax community.	Measurement of oxygen; pollution

BIOLOGY IDEA 5: ECOLOGY, Investigation 1 (2-4 periods)

The bean plants needed for Investigation 2 should now be three to four weeks old.

PURPOSE: Develop the concept that living things need energy.

DEVELOPMENT: The students burn a candle and various kinds of food to heat a measured amount of water. From their measurements, the students are asked to calculate a unit of energy called a Candle Calorie. They are led to see that living things burn up food which is a source of energy.

HIGHLIGHT: The questions in part C guide the students to see the relationship between various energy sources and how they are used. This leads to the understanding that living things need energy.

MATERIALS (for each team of two)

- Candle, small birthday
- Play-Doh, small piece
- Ringstand
- Ringstand clamp
- Test tube
- Thermometer
- Stirring rod
- Matches
- Stopper, cork
- Pin, straight[1]
- Peanut
- Other foods, such as brazil nut, almond, sugar cube, and bread
- Can, small frozen juice type (optional)[2]

Preparation of Materials

1. Remove the head from the straight pin and insert the cut end into a cork stopper.
2. Cut out a 1" strip in one side of the frozen juice can.

TEACHING TIPS

Responses to Expect: The students may be confused with Table 1 because it is rather large and complicated. Even though each column in the table is keyed with a letter corresponding to the steps in the procedure, you should point this fact out and assist the students in putting their data in the right places.

Even though the math involved is simple subtraction and division, the students will probably need help in calculating the temperature change of the water (h) and the amount of candle burned (i).

Similarly, the students will have to be shown how to find the Candle Calorie (j). Before proceeding to part B, explain the concept of the Candle Calorie.

If the students tend to be careless in lab techniques, it will be reflected in their data. Stress the significance of the quantity of water used, the distance between the test tube and the apex of the unburned item, the stirring of the water before the reading of the temperature, and the burning time.

Practical Hints: A frozen juice can could act as a barrier to extraneous drafts while burning the various foods. In addition, it provides a tube for convection currents to flow upwards as in a chimney.

Check the type of candle and the various foods you plan to use to see if they will burn easily and for at least 1-2 minutes. If any food will not burn for 2 minutes, you can either reduce the burning time of the candle or mathematically adjust all the numbers to correspond.

Instead of having all the teams test the same foods, you may want different teams to test different items. The class, of course, will then have to exchange their data to complete Table 1.

Fill a 50 ml beaker half full of sugar. Add 10-15 ml concentrated sulfuric acid. The resulting cloud of smoke, heat, and residue of burnt carbon may help you illustrate the concept of heat energy.

Discussion and Review: Discussion should center around the student data in Table 1.

ENRICHMENT

1. Have students choose and test other foods.
2. Prepare a paper on calories, exercise, and dieting.
3. Explain the history of the calorie.

REFERENCES

Books and Articles

Baker, Jeffrey, and Garland E. Allen, *The Study of Biology.* Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1967.

McElroy, William D., et al, *Foundations of Biology.* Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1968.

Multi-Media Aids

Food, the Color of Life: 16 mm, color, 26 min., Association Films S-983.

The World Around Us: 16 mm, color, 25 min., McGraw-Hill 672406.

POSSIBLE ANSWERS

1. (Nuts that are particularly oily will score high.)
2. Energy.
3. Energy.
4. Burn (or break down).
5. Burn it in an engine.
6. Burn the food (or break it down).
7. Energy.
8. Energy.

CONCEPT SUMMARY: All living things constantly need energy.

TABLE NO. 1

THE ENERGY OUTPUT OF VARIOUS SUBSTANCES, IN CANDLE CALORIES

Substance Burned	Amount of Water, ml	(d) Initial Temperature of Water, °C	(f) Final Temperature of Water, °C	(h) Difference in Temp., °C (f) - (d)	(a) Weight of Unburned Substance, g	(g) Weight of Burned Substance, g	(i) Difference in Weight, g (a) - (g)	(j) Candle Calories (h) ÷ (i)
Candle	10	21	43	12	0.9	0.75	0.15	200
		19	47	28 $\boxed{20}$	0.65	0.6	0.05 $\boxed{0.1}$	
Peanut	10	19	89	70	1.0	0.3	0.7	86.8
		18	87	69 $\boxed{69.5}$	1.0	0.1	0.9 $\boxed{0.8}$	
Almond	10	19	57	38	1.3	0.7	0.6	88
		16	66	50 $\boxed{44}$	0.9	0.5	0.4 $\boxed{0.5}$	
Brazil Nut	10	18	67	49	3.0	2.6	0.4	138
		19	39	20 $\boxed{34.5}$	3.6	3.5	0.1 $\boxed{0.25}$	

You will need 3-4 week-old bean plants for this investigation. Smear the leaves on one of the plants with petroleum jelly or cover with plastic wrap 3-4 days before the experiment in part C. Place another bean plant in the dark for 3-5 days before the experiment in part D.

PURPOSE: Develop the concept that plants need carbon dioxide and light to make starch.

DEVELOPMENT: The students will test for the presence of starch in plant leaves covered to prevent the entrance of carbon dioxide and in other plant leaves kept in the dark. The results of these two tests will be compared with the test on a control plant to show that carbon dioxide and light are needed for a plant to make starch.

HIGHLIGHT: The major highlight comes when the student finds that the plants kept in the dark and in the absence of carbon dioxide do not have any starch.

MATERIALS (for each team of two)

- Leaf
- Forceps
- Microscope slide
- Cover slip
- Microscope
- Beaker, 100-250 ml
- Ringstand
- Burner
- Test tube
- Alcohol, methyl or ethyl
- Petri dish
- Lugol's solution

MATERIALS (for teacher)

- Bean plants, 3-4 weeks old
- Petroleum jelly or plastic (Saran) wrap
- Scissors

Preparation of Materials

1. Grow some Kentucky Wonder bean seeds in individual flower pots. Start these seeds 3-4 weeks before this investigation.

2. Smear petroleum jelly over the leaves of one plant or cover them with plastic wrap 3-4 days before part C.

3. Put one plant in the dark for 3-5 days before part D.

4. You can prepare your own Lugol's solution by dissolving 6 g of KI in 100 ml water. Then add 4 g iodine (I_2) crystals.

TEACHING TIPS

Responses to Expect: To avoid confusion, have the students do the four distinct parts of this investigation slowly and separately.

Practical Hints: Save on the amount of glassware needed by having all the students process their leaf parts in a common beaker and test tube.

You do not have to use bean plants. There are many other kinds of plants that are just as suitable; e.g., coleus, tomato, and geranium.

You will need a minimum of three plants; however, grow 6-9 plants to be safe. One plant will serve as the control. One plant should have each of its leaves covered with petroleum jelly or plastic (Saran) wrap for 3-4 days. If you wrap the entire plant in plastic wrap, place a beaker full of KOH crystals inside to absorb all of the carbon dioxide gas. A third plant should be kept in a dark cabinet for 3-5 days.

Have the students place their leaf parts in the boiling water as quickly as possible. If the leaves are exposed to carbon dioxide or light for any length of time, photosynthesis may occur.

Discussion and Review: The questions in part E summarize the four experiments in this investigation. Use these questions for discussion.

ENRICHMENT

1. Run a starch test comparing leaves that have had petroleum jelly smeared on their top side only, their bottom side only, and both sides.
2. Run a starch test on leaves that are variegated.

REFERENCES

Books and Articles

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Butler, W. L., and Robert J. Downs, "Light and Plant Development," *Scientific American,* December, 1960.

Gabriel, M. L., and S. Fogel, eds., *Great Experiments in Biology.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1955.

Smallwood, William L., and Edna R. Green, *Biology.* Morristown, N.J.: Silver-Burdett Co., 1968.

van Overbeek, Johannes, and Harry K. Wong, *The Lore of Living Plants.* New York: Scholastic Book Services, 1964.

Multi-Media Aids

Green Plants–Autotrophic Nutrition: Micro-slide kit, National Teaching Aids.

Green Plants and Sunlight: 16 mm, color, 11 min., Encyclopaedia Britannica 2487.

The Growth of Plants: 16 mm, color, 21 min., Encyclopaedia Britannica 1962.

Life in the Sea: 16 mm, color, 11 min., Encyclopaedia Britannica 1577.

Light Requirement for Starch Production in Green Plants: 8 mm film loop, color, Encyclopaedia Britannica 81186.

Photosynthesis: Carbon Dioxide Requirement, I: 8 mm film loop, color, Encyclopaedia Britannica 81187.

Photosynthesis: Carbon Dioxide Requirement, II: 8 mm film loop, color, Encyclopaedia Britannica 81188.

Testing for Starch in Green Plants: 8 mm film loop, color, Encyclopaedia Britannica 81185.

POSSIBLE ANSWERS

Space *a:* Student drawing.

1. The stomates allow air to enter and leave.

TABLE NO. 1

THE PRESENCE OF STARCH IN BEAN PLANTS KEPT UNDER VARIOUS CONDITIONS

Treatment	Evidence of Starch
Control	Yes
Leaves covered with jelly or plastic wrap	No
Dark	No

2. Carbon dioxide.
3. It will not contain any starch.
4. Starch.
5. It did not allow carbon dioxide to enter the leaves.
6. A plant needs carbon dioxide to make starch.
7. Starch.
8. Light.
9. A plant needs light to make starch.
10. Stomates.
11. Starch.
12. Starch.
13. Carbon dioxide.
14. When carbon dioxide is excluded by petroleum jelly or plastic wrap, no starch is made.

15. Through the stomates.
16. When petroleum jelly or plastic wrap seals the stomates, no starch is made.
17. Starch.
18. Starch.

CONCEPT SUMMARY: A plant must have carbon dioxide and light to make starch.

BIOLOGY IDEA 5: ECOLOGY, Investigation 3 (2-3 periods)

PURPOSE: Develop the concept that plants need chlorophyll to maintain life.

DEVELOPMENT: The students will separate chlorophyll pigments using the technique of paper chromatography. By examining a series of data about chlorophyll, the students will find that plants need chlorophyll to sustain life.

HIGHLIGHT: The importance of plant pigments is dramatized when the student studies the data about bleached and unbleached *Euglena*, and sees that chlorophyll is necessary for the continuance of plant life.

LOOK AHEAD: Investigation 9 should be started now because it runs the remaining duration of Idea 5.

MATERIALS (for each team of two)

- Leaves
- Mortar and pestle
- Sand, coarse
- Acetone, 5 ml
- Test tube, large
- Filter paper strip
- Stopper, cork
- Ringstand
- Ring clamp
- Chromatographic solvent[2]
- Paper clip
- Toothpick

Preparation of Materials

1. The chromatographic apparatus should be assembled as pictured in the student text. The hook is cut from a paper clip. A filter paper strip is cut to fit inside the test tube and is hung from the hook.

2. Mix together 92 ml petroleum ether and 8 ml acetone for the chromatographic solvent.

TEACHING TIPS

Responses to Expect: You can probably expect more than the average share of careless lab technique due to the fact that slower students are usually poor in following directions. Although the IIS program is designed for the students to inquire, rather than follow explicit directions, the students will need fairly respectable chromatograms before discussing any of the questions intelligently.

The students will have a tendency to put too much acetone in the mortar when grinding the leaves. Have them add the acetone a drop at a time. Only one drop should be applied to each chromatogram.

Practical Hints: Excellent chromatograms can be made if the following hints are followed:

a. Draw a line on the filter paper with pencil only.

b. Cut the tip of the filter paper to a point.

c. The drop of chloroplast pigment applied to the filter paper should give as concentrated and as small a spot as possible. The student will have to exercise patience in applying the spot with the use of a toothpick. He should blow on the spot to dry it.

d. The filter paper strip must hang free inside the test tube.

e. The level of the solvent must be below the spot.

f. Do not allow the solvent level to rise up to the hook. Remove the strip when the solvent reaches the hook or 20-30 minutes have elapsed.

Discussion and Review: Review the concepts studied in Investigations 1 and 2 in relation to the concept being developed in this investigation.

The implications of the experiments described in parts B and C can be discussed with the entire class, or part B can be discussed with the class and the students can do part C on their own.

ENRICHMENT

1. Have the students do a more detailed analysis of the pigment bands on the chromatogram.
2. Do a comparative study of the pigments from different plants.
3. Prepare a paper on the light phase of photosynthesis.

REFERENCES

Books and Articles

Bold, Harold C., *The Plant Kingdom.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Biological Sciences Curriculum Study, *Biological Science: an Inquiry into Life.* New York: Harcourt, Brace & World, 1968.

Gaffron, Hans, *Photosynthesis,* BSCS Pamphlet Series, No. 24. Boston: D.C. Heath, 1965.

Moore, Harold A., and John R. Carlock, *The Spectrum of Life.* New York: Harper & Row, 1970.

Rabinowitch, Eugene, "Progress in Photosynthesis," *Scientific American,* November, 1953.

Wald, George, "Life and Light," *Scientific American,* October, 1959.

Multi-Media Aids

Chlorophyll–Capturing the Sun's Energy: Filmstrip, color, 40 frames, Popular Science 1502.

Colors of Light and Photosynthetic Efficiency: 8 mm film loop, color, Encyclopaedia Britannica 81273.

Green Plants and Sunlight: 16 mm, color, 11 min., Encyclopaedia Britannica 2487.

Paper Chromatography: 8 mm film loop, color, Thorne 27-1.

Photosynthesis: Chemistry of Food-making: 16 mm, color, 13.5 min., Coronet 1500.

POSSIBLE ANSWERS

Space *a:* Student chromatogram.

1. Bubbling.
2. Carbon dioxide.
3. No. Shredded leaves give off bubbles, too.
4. Bubbling.
5. Chloroplasts and carbon dioxide.
6. Carbon dioxide.
7. Chloroplasts.
8. Untreated ones.
9. The treated ones.
10. The green substance is necessary for life to continue.
11. The green substance.

12. Chlorophyll.
13. Chlorophyll.

CONCEPT SUMMARY: Plants need chlorophyll to maintain life.

BIOLOGY IDEA 5: ECOLOGY, Investigation 4 (2-3 periods)

PURPOSE: Develop the concept that plants produce oxygen.

DEVELOPMENT: Using a respirometer, the students measure the output of a gas from a plant. Then the students are asked to interpret a series of experiments performed by Joseph Priestly to see the significance of oxygen.

HIGHLIGHT: The use of the respirometer to measure the gas output of a plant can be fun; however, the nature of the gas is meaningless until the student reads about Priestly's experiments. The latter is the highlight of this investigation.

MATERIALS (for each team of two)

- Test tube, large
- 1% sodium bicarbonate solution, 25 ml[1]
- *Elodea*
- Stopper, rubber, two-hole
- Tubing, rubber, 10"
- Tubing, glass, 8-10" x 1-1.5 mm (i.d.)[2]
- Clamp or clothes pin
- Ruler
- Light
- Ink
- Dropper with drawn out tip

Preparation of Materials

1. 1% sodium bicarbonate solution is 1 g $NaHCO_3$ in 100 ml water.

2. Tape the length of glass tubing to a ruler. This will prevent breakage and facilitate handling of the tubing.

TEACHING TIPS

Responses to Expect: A few students will allow the ink drop to run out of the tube. They will need time to become familiar with the setup.

Practical Hints: If you do not have any *Elodea,* try shredded leaves.

To economize on glassware, have one team of students serve as the control. The control tube should be identical to all of the experimental tubes except that it will be lacking *Elodea.*

Placing the ink drop in the capillary is difficult. Although directions are given for this in the student text, you may find it best to add the ink yourself, before class.

If the ink drop moves in the control, this movement should be compensated for in all of the experimental data. For instance, if the control drop moved forward 1 mm, subtract 1 mm from all of the experimental data. Any movement of the control bubble will probably be due to temperature changes. Therefore, try to keep all of the tubes at a constant temperature.

Caution the students to correctly read the distance the drop moves. To do this, the student must read the point at the front of the drop at all times.

Although the directions ask the students to run the experiment for 1-3 minutes, it may be necessary to run the experiment longer if the plants are not photosynthesizing fast enough.

Discussion and Review: Be sure to review the concepts studied in Investigations 1-3. The concepts developed there are sequentially important to the development of the concept in this investigation.

The application of the data gathered in the experiment becomes meaningful in the discussion of part B.

ENRICHMENT

1. Adjust the light source to different distances. Then have the students correlate the effect of light intensity on photosynthesis as measured by the rate of oxygen production.
2. Do a more extensive paper on the Priestly experiment.

REFERENCES

Books and Articles

Devlin, Robert M., *Plant Physiology*. New York: Reinhold Publishing Corp., 1966.

Englemann, T. W., "On the Production of Oxygen," *Great Experiments in Biology,* M. Gabriel and S. Fogel, eds. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1955.

Fitzpatrick, Frederick L., *Our Plant Resources.* New York: Holt, Rinehart & Winston, 1964.

Galston, A. W., *Life of the Green Plant,* 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Ingenhousz, Jan, *Experiments upon Vegetables, Discovering Their Great Power of Purifying the Common Air in Sunshine and Injuring It in the Shade and at Night.* London: Elnsley and Payne, 1779.

Priestly, Joseph, "Observations on Different Kinds of Air," *Philosophical Transactions of the Royal Society of London,* Vol. 62, 1772, p. 147.

Rosenburg, Jerome L., *Photosynthesis.* New York: Holt, Rinehart & Winston, 1965.

Multi-Media Aids

Biochemistry of Photosynthesis: 8 mm film loop set, color, 2 film loops, Popular Science ISB.

Foods and Nutrition: 16 mm, black and white, 11 min., Encyclopaedia Britannica 218.

Green Plants: 16 mm, color, 10 min., McGraw-Hill 404251.

Photosynthesis: Factors Affecting Oxygen Production: 8 mm film loop, color, Encyclopaedia Britannica 81190.

POSSIBLE ANSWERS

1. Two, light and temperature.
2. One.
3. Yes, away from the plant.
4. Producing a gas, which moves the ink drop away.
5. Run a similar experiment without a plant in the test tube.
6. Oxygen.
7. Lack of oxygen.
8. The mouse used up the oxygen. This reduced the air pressure and caused the water level to rise.
9. It produced oxygen. This increased the air pressure and caused the water level to drop.
10. Oxygen.
11. Oxygen.

CONCEPT SUMMARY: Plants produce oxygen.

TABLE NO. 1

THE PRODUCTION OF GAS BY *ELODEA*, WITH AND WITHOUT LIGHT

Condition	Temperature, °C	Time, min.	Ink Drop at Start, cm	Ink Drop at End, cm	Distance Moved, cm
Light	22	5	7.5	7.9	0.4
Dark	22	5	10.3	10.3	0.0

Prepare a yeast culture one day before starting this investigation.

PURPOSE: Develop the concept that carbon dioxide is given off when food is broken down and energy is released.

DEVELOPMENT: The student is shown two tubes of yeast (one of which is actively bubbling) and asked to predict and design an experiment to explain the bubbling.

Bubbles in the yeast culture are tested for the presence of carbon dioxide. The results of this experiment, compared to a graph about the respiration of yeast, show that carbon dioxide is given off when food is broken down for energy.

HIGHLIGHTS: The initial highlight comes when the student is confronted with a discrepant event and must design an experiment to explain its cause.

The culminating highlight comes when the student examines a graph about the respiration of yeast and sees the relationship between carbon dioxide and food breakdown.

MATERIALS (for each team of two)

- Test tubes, two (25 x 200 mm preferred)
- Stopper, one-hole
- Tubing, glass, short length to fit stopper
- Tubing rubber, 6-8"
- Yeast culture[1]
- Limewater[3]

MATERIALS (for teacher)

- Test tubes, four (25 x 200 mm preferred)
- Stopper, one-hole, two
- Tubing, glass, short length to fit stopper, two
- Tubing rubber, 6-8", two
- Yeast culture
- Limewater
- (Additional materials will depend on what the students wish to test.)

Preparation of Materials

1. To prepare yeast culture, mix one package dry yeast in 500 ml water with 125 g brown sugar. Pour some of the yeast culture into two test tubes. Store one tube in the refrigerator for 8-12 hours. Leave the other tube and the remaining yeast culture at room temperature for 8-12 hours.

2. Prepare the apparatus as shown on page 239 in the student text.

3. To prepare limewater, slowly add calcium oxide to a quantity of water, shaking continuously, until no more will dissolve in the water. Let the excess calcium oxide settle to the bottom. Use the clear supernatant.

TEACHING TIPS

Responses to Expect: The experiment is entirely unstructured. The students will expect specific directions on the procedure to follow. Questions 3-7 should help the students think about how to structure their experiments.

Practical Hints: One day before the lesson, prepare a culture of yeast. Pour some of the yeast into each of two test tubes. Leave one tube at room temperature. Place the other tube in a refrigerator. The next day, stopper each tube and attach a length of rubber tubing to each test tube as pictured on page 239 in the student text. Run each length of tubing into a test tube of water and set before the class.

Ask the students to observe and answer question 1. Follow this by asking the students to propose explanations for their observations. These predictions are to be listed under question 2. All responses should be treated as valid responses.

Have the students answer questions 3-7 next, perhaps followed with a class discussion of these same questions. Temperature is one of the easiest variables to test. If the students decide to test the temperature factor, you can divide the class into three different kinds of groups. Give one group a beaker of ice water, another group a beaker with water at room temperature, and the last group a beaker with warm water. A stirring rod and thermometer should also be supplied. The group will place their test tubes of yeast in the beakers of water.

The tubes of yeast should sit in the beakers for at least five minutes to allow the temperature of the yeast to equilibrate before any readings are taken.

Have the students do part C on their own. However, you may have to collect the class data before the students can draw their graph and answer question 9.

Since it takes a fair amount of carbon dioxide to turn the limewater cloudy, it is suggested that you do part C as a class demonstration. Put some day-old yeast culture in a 125-250 ml flask. Add a pinch of sugar and then stopper with a one-hole stopper. Pipe the evolving gas into a test tube of limewater.

Discussion and Review: The students should be able to answer all the questions from "13" to the end on their own.

ENRICHMENT

1. The students can test some of their other predictions.
2. Prepare a paper on the subject of fermentation.

REFERENCES

Books and Articles

Asimov, Isaac, *The Chemicals of Life.* New York: Signet Science Library, 1962.

Asimov, Isaac, *Life and Energy.* Garden City, N.Y.: Doubleday & Co., Inc., 1962.

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Lehninger, Albert L., *Bioenergetics.* New York: W. A. Benjamin, 1965.

McElroy, William D., *Cell Physiology and Biochemistry,* 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Scrimshaw, N. S., "Food," *Scientific American,* September, 1963.

Multi-Media Aids

Carbon Dioxide Production by Living Cells: 8 mm film loop, color, Encyclopaedia Britannica 81198.

Food Energy and You: 16 mm, color, 21 min., Association Films.

Nutrition: Energy, Growth and Repair: Filmstrip, color, 40 frames, Popular Science 613.

The Secret of Life: 16 mm, color, 24 min., McGraw-Hill 672412.

POSSIBLE ANSWERS

1. There are bubbles coming from one tube.
2. a. There are different amounts of sugar in each tube.
   b. There are different amounts of yeast in each tube.
   c. Each tube was kept at a different temperature.
   d. Each tube has yeast that is of a different age.
   e. Each tube has been subjected to a different amount of light.
3. No, one at a time for proper controls.
4. Test each prediction.
5. Temperature (encourage students to do this one).
6. Keep all factors identical except for a difference in temperature.
7. Keep one tube in warm water and one in ice water and count the number of bubbles.
8. Bubbles per minute.

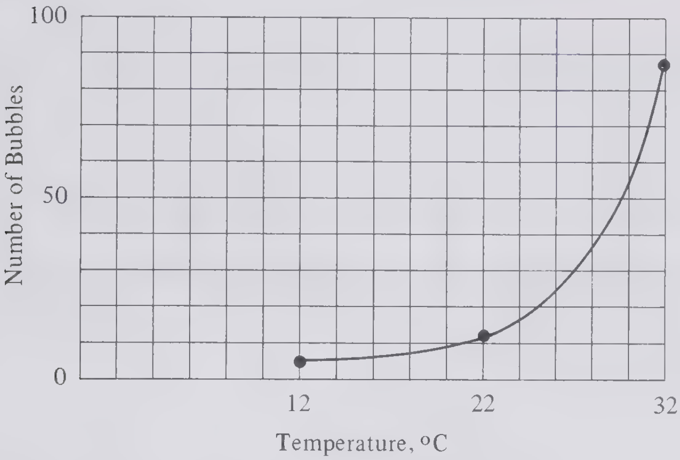
TABLE NO. 1

THE NUMBER OF BUBBLES GIVEN OFF BY YEAST KEPT AT DIFFERENT TEMPERATURES

Temperature, °C.	Time, Min.	Number of Bubbles
12	5	5
22	5	13
32	5	87

GRAPH NO. 1

A COMPARISON OF BUBBLES GIVEN OFF BY YEAST KEPT AT DIFFERENT TEMPERATURES



9. More bubbles are produced at warmer temperatures.
10. Gas leakage, temperature variation, reading the number of bubbles incorrectly.
11. It turns cloudy.
12. Carbon dioxide.
13. They are using up their food source, the sugar.
14. It is the source of energy.
15. Energy.
16. Break it down.
17. Breakage of the sugar.
18. It must be broken down.
19. Energy.
20. Carbon dioxide.

CONCEPT SUMMARY: Carbon dioxide is released when food is broken down for energy.

BIOLOGY IDEA 5: ECOLOGY, Investigation 6 (2-4 periods)

PURPOSE: Develop the concept that living things need oxygen to release energy from food if life is to continue.

DEVELOPMENT: The students will use a respirometer to measure the amount of oxygen used by a group of soaked and boiled pea seeds. The data will show that germinating seeds respire whereas dead pea seeds do not.

HIGHLIGHT: The climax to this investigation is developed in two stages. The students begin by measuring the respiration rate of soaked pea seeds and boiled pea seeds. Then they develop a model that explains how energy is captured during the process of synthesis and released during respiration.

LOOK AHEAD: Start the experiment in part A, Investigation 8. It takes 10-14 days to complete.

MATERIALS (for each team of two or four)

Respirometer apparatus, two[1]
Cotton
Potassium hydroxide, 30 pellets
Pea seeds, to fill two test tubes half full[2]
Forceps

Preparation of Materials

1. See Investigation 4 for instructions on how to set up the respirometer.
2. Soak half of the pea seeds 12-24 hours before needed. Boil the other half of the pea seeds for 10 minutes. They can then be stored in water until needed.

TEACHING TIPS

Responses to Expect: The students may try to handle the potassium hydroxide with their hands. Caution them to use the forceps because the potassium hydroxide can be caustic when handled with wet or sweaty hands.

The students may be anxious to start collecting data immediately after setting up the respirometer. They must wait at least 2-3 minutes for the conditions in the tubes to equilibrate.

Practical Hints: You may want to work in groups of four for this investigation. Within each group, two students can set up and observe one of the respirometers.

Use the largest test tubes you can obtain. In this way, more oxygen will be used up and the movement of the ink drop will be more perceptible.

There is no need to set up and clean out the tubes for every class. Simply remove the clamp from the shorter rubber tube between classes.

There will be a more positive respirometer reading with seeds that are soaked a longer period of time. Therefore, soak the seeds a full 24 hours, if possible.

Discussion and Review: Review all of the past concepts because they are central to the development of the idea of synthesis. From here on, all of the concepts will be concerned with how energy is released from food and used by living things for survival.

An important model is developed in part B, a model of synthesis and respiration. It is highly recommended that the teacher help the entire class interpret each paragraph and illustration in part B. Then the students can answer the questions on their own.

ENRICHMENT

1. Measure the respiration rate of various types of seeds.
2. Prepare a brief description of how starch is broken down into sugar.

REFERENCES

Books and Articles

Cheldelin, Vernon H., and R. W. Newburgh, *The Chemistry of Some Life Processes.* New York: Reinhold Publishing Corp., 1964.

Gerard, R.W., *Unresting Cells.* New York: Harper & Row, 1949.

Jevons, F. R., *The Biochemical Approach to Life.* New York: Basic Books, 1964.

Lehninger, A., "Energy Transformation in the Cell," *Scientific American,* May, 1960.

Lehninger, A., "How Cells Transform Energy," *Scientific American,* September, 1961.

Mirsky, A.E., and V.G. Allfrey, "How Cells Make Molecules," *Scientific American,* September, 1961.

Multi-Media Aids

The Chemical Lab in Your Body: Filmstrip, color, 40 frames, Popular Science 578.

How a Hamburger Turns You On: 16 mm, color, 20 min., Association Films.

POSSIBLE ANSWERS

TABLE NO. 1

THE ABSORPTION OF GAS BY PEAS KEPT UNDER TWO CONDITIONS

Condition of Seed	Movement of Ink Drop in 3-5 Minutes, mm		
	Ink Drop at Start, mm	Ink Drop at End, mm	Distance Moved, mm
Soaked	5 9 12	5.5 9.5 12.2	0.5 0.5 0.2
Boiled	10 10 11.5	10 10 10.5	0.0 0.0 -1.0

1. The boiling killed the seeds and the soaking started them germinating.
2. Movement of the ink drop toward the test tube.
3. Ink drop moved toward soaked seeds only.
4. Absorbing a gas.
5. Oxygen.
6. Only one ink drop moved, the one connected to the soaked seeds.
7. Oxygen.
8. The stored food in the seed.
9. Oxygen.
10. The sun.

11. Carbon dioxide.
12. Water, sunlight, chlorophyll.
13. Oxygen.
14. They must be broken down into smaller molecules.
15. Energy.

CONCEPT SUMMARY: Living things need oxygen to release energy if life is to continue.

BIOLOGY IDEA 5: ECOLOGY, Investigation 7 (3-5 days)

PURPOSE: Develop the concept that a community is an organized group of populations living in mutual dependence.

DEVELOPMENT: The students will make an ecological survey of a specific area. If there are enough interacting organisms observed in the area studied, the students may see a community in operation.

HIGHLIGHT: By means of ecological surveys, the students will see the meaning of community life in nature.

MATERIALS (for each team of two)

The materials needed will depend upon the area selected for study and the degree of study desired by the teacher.

The minimum materials needed will be:

- Microscope
- Microscope slides
- Cover slips
- Hand lens
- Ruler
- Meter stick
- String
- Stakes

TEACHING TIPS

Responses to Expect: The students will have a natural tendency to gloss over the survey area, especially if the area to survey is too large. Give the students an area of about one square foot and ask them to account for every form of life in that small area.

Students may complain that they do not know the names of the organisms. Knowing the names of organisms is not important. The organisms are to be classified into common groups, e.g., grasses, bugs, trees with needles, trees with leaves. The purpose of the lesson is to make a survey or census of the area, not to learn and memorize the names of various organisms.

Practical Hints: Do not send your class out to make its survey until they know what they are to look for. There are six factors suggested in part D.

Bring samples into the class from the area you have selected for the students. Help them to understand that they are to identify, count, and group the organisms by common characteristics. Show them examples of grasses, bugs, broadleaf plants, and needlelike plants.

Have a data table, designed by the class, completed before venturing out into the field.

Stake out an area into one-foot squares using the suggested pattern illustrated on top of page 208.

The purpose of this pattern is:

a. to give the student a small enough area that he can account for every organism in the area.

b. to put him in close proximity to other students so that there is an exchange of questions and answers.

c. to be able to pool the data from several classes into a larger picture of the community.

Discussion and Review: Review the concept of a population and a society before examining the data from the field survey. The discussion of the composite field survey will hopefully then yield the picture of a community.

The limited survey taken by the students may not reveal the picture of an interacting and interdependent community. In order for this to happen, they will have to observe the area over a longer period of time. They will be doing this in the next two investigations. Supplemental movies, field trips, and class discussions may be necessary before the students can answer the last three questions.

ENRICHMENT

1. Have the students make a continuous survey of an area over a longer period of time.
2. Have the students make a comparative survey of a number of different types of ecological areas.

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The Desert Community: 16 mm, color, 12 min., Encyclopaedia Britannica 2301.

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Life in the Oceans: Filmstrip, color, 40 frames, Popular Science 1539.

Life in the Soil: Filmstrip, color, 40 frames, Popular Science 1549.

Life in the Woodlot: 16 mm, color, 17 min., McGraw-Hill 654955.

The Liverworts: Adaptations to Terrestrial Life: 16 mm, color, 10 min., McGraw-Hill 682711.

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The Living Tide, Part 2: The Brim of Sand: 16 mm, color, 27 min., McGraw-Hill 644601.

The Living Tide, Part 3: The Edge of the Sea: 16 mm, color, 31 min., McGraw-Hill 644602.

The Physical Environment: 16 mm, color, 11 min., Encyclopaedia Britannica 2136.

Plant-Animal Communities: The Changing Balance of Nature: 16 mm, color, 11 min., Coronet 1287.

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Recognizing Edge Community Organisms: 8 mm film loop, color, Encyclopaedia Britannica 80147.

The Sea: 16 mm, color, 26 min., Encyclopaedia Britannica 2005.

The Spruce Bog: 16 mm, color, 23 min., McGraw-Hill 633502.

Termite Colony: A Complex Social Organization: 16 mm, color, 11 min., Coronet 1699.
Tidal Pool Zoo: Filmstrip, color, 40 frames, Popular Science 1527.
World in a Marsh: 16 mm, color, 22 min., McGraw-Hill 633504.

POSSIBLE ANSWERS

1. Fleas.
2. The dog.
3. Specific kinds of trees; the number of each; and in what area.
4. It would never come close enough for handouts or to scavenge.
5. It would be caught and killed.
6. It is a successful adaptation of caution and tameness.
7. (Will vary with data.)
8. Normally no, because populations interact.
9. (Look for examples of commensalism and mutualism.)
10. (Look for predator-prey relationships.)
11. (Will vary with data.)
12. (Will vary with data.)
13. Living in cooperative harmony with one another; dependent upon each other for energy.
14. Energy.
15. Community.

CONCEPT SUMMARY: A community is an organized group of populations living in mutual dependence.

Begin part A when you start Investigation 6.

PURPOSE: Develop the concept that living things compete for energy in an intricate food web pattern.

DEVELOPMENT: A piece of paper is subjected to bacterial decomposition and some bacteria are subjected to antibiotic action.

The student sees a simple food chain, and from further reading, he is shown that various food chains are linked together in an intricate food web pattern.

HIGHLIGHTS: The students place antibiotic discs in a dish of bacteria and observe zones of inhibition around the discs.

In addition, they spread a soil dilution across a dish of bacteria. After a few days, zones of inhibition indicate how certain species of soil organisms compete with other organisms for energy.

MATERIALS (for each team of two)

- Test tubes, two
- Soil, rich garden, 1 g
- Graduated cylinder, 10 ml
- Paper strip to fit test tubes, two
- Balance
- Cotton
- Petri dish with nutrient agar, two[1]
- L-shaped glass rod[2]
- Antibiotic discs[3]
- Forceps

MATERIALS (for teacher)

- Culture of *B. subtilus* or *B. cereus*[4]

Preparation of Materials

1. Prepare 20 ml nutrient agar for each dish. Place the required amount of cold water in a saucepan. Add 24 g nutrient agar per liter of water. Stir and heat to a boil. Dispense 20 ml of the agar into each Petri dish and sterilize at 15 lbs/sq in. pressure for 20 minutes. If you are using sterile plastic Petri dishes, sterilize the flask of nutrient agar before dispensing.

2. Bend a glass rod into the shape of an "L," with the bottom of the "L" slightly larger than the radius of the Petri dish.

3. Purchase antibiotic discs from Scientific Products or any Difco distributor. It is suggested that you buy streptomycin, aureomycin, and vancomycin. Do not buy penicillin, because the bacteria strains suggested are mutant strains resistant to penicillin.

4. Prepare 250 ml of sterile nutrient broth by adding 2 g nutrient broth to 250 ml cold water. Heat to dissolve the broth. Stopper the broth in a 500 ml flask and sterilize at 15 lbs/sq in. pressure for 20 minutes. Aseptically transfer a loop of *B. subtilus* or *B. cereus* to the sterilized broth and incubate overnight at 25-37°C. Cultures of the two bacteria can be purchased from any biological supply house.

TEACHING TIPS

Responses to Expect: Since most of the students have never handled bacteria before, expect stray bacterial growth to occur in some of the dishes. However, the antibiotics will probably still react against the stray growth.

Practical Hints: There is no need to have each group of students make their own 1 g soil dilutions in a liter of water for use in part A. The teacher or one group of students can make a dilution for the entire class.

Use a fairly pulpy paper in part A. Filter paper is ideal.

There is no need to flame the L-shaped glass rods. Too many of the rods will crack with this method. Instead, store all of the rods in a beaker of alcohol. The students can use the rods directly from the beaker.

When the L-shaped rod is used, the spreading action is actually accomplished by rotating the dish with one hand while the other hand holds the rod steady.

The sterilized forceps mentioned in step e are simply stored in a small beaker of alcohol. You may not need the forceps because some of the manufacturers of antibiotic discs package their discs in an automatic dispenser.

Discussion and Review: The introductory paragraphs should be read with the emphasis on the constant need of all organisms for energy.

While the paper is decomposing in the test tube, discuss the material between questions 11 and 12. This will provide a background for what is happening in the tube.

Likewise, discuss Fleming's discovery to provide the background for understanding antibiotic action.

Finally, part D should be discussed to develop the concepts of food chains and food webs.

ENRICHMENT

1. Compare the lysing action of various antibiotics on different bacteria.
2. Do a paper on the operations of a sewage plant.
3. Do a paper on the search for new antibiotics.

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What Is Ecology?: 16 mm, color, 11 min., Encyclopaedia Britannica 1916.

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POSSIBLE ANSWERS

1. Yes. The paper turned brown (or gray).
2. The paper in the unsterilized tube broke.
3. The sterilized tube.
4. To kill all living things in the soil.
5. Something in the soil water was reacting with the paper.
6. Yes, the one with the brown line (unsterilized).
7. No, because the sterilization killed whatever was causing the paper to break.

8. Probably some microscopic organisms.
9. The microorganisms need oxygen.
10. The microorganisms were digesting the paper, causing it to decompose.
11. Microorganisms digest and cause them to decompose.
12. Microorganisms or bacteria. (Students should have written this answer in the blank in Diagram 1 on their data sheets.)

Space *a:* Student drawing.

Space *b:* Student drawing.

13. No, there is no growth around the discs and around certain forms of growth.
14. The substance in the paper circle and the substance secreted by the other organisms prevent bacterial growth.
15. Food and energy.
16. Secreting a substance.
17. Dead animals.
18. From the sun, by photosynthesis.
19. Protozoa.
20. Copepods, larvas, and worms.
21. Fish.
22. Polar bears and Arctic foxes.
23. Remains of seals and dung.
24. Insects and ptarmigans eat plants; spiders and ptarmigans eat insects; spiders eat ptarmigans.
25. Food and energy.
26. A complex network of food chains in a mutually dependent community.

CONCEPT SUMMARY: All living things compete with other living things for energy in a food web.

BIOLOGY IDEA 5: ECOLOGY, Investigation 9 (4-6 weeks)

Start this investigation after Investigation 2.

PURPOSE: Develop the concept that a succession of types of organisms can be observed in a community until an equilibrium or climax is established.

DEVELOPMENT: Over a 4-6 week period, the students observe a community of organisms in a sealed environmental system. It is hoped that a climax community will result by the end of the observation period.

HIGHLIGHT: After several weeks of observation, the students will see a population change take place in the closed community. Their observations become meaningful when the concept of a climax forest is discussed and illustrated.

MATERIALS (for each team of two)

Flask, tissue culture[1]
Culture media[2]
Microscope, compound

Preparation of Materials

1. If you do not have an IIS equipment package, purchase the type of flask made by Falcon Plastics, 3012.

2. For culture media, obtain pond or aquarium water which contains an abundant amount of plant and animal life.

TEACHING TIPS

Responses to Expect: The students may lose interest in this rather long task. To prevent this from happening:

a. Reduce the number of observations from two to one time per week as the community reaches a climax.

b. Do not allow the students to observe their flasks for any great length of time during a period.

c. Do not require the students to identify the organisms.

d. Give the students media for their flasks that contain an abundant quantity of microscopic organisms.

Practical Hints: The clear plastic flasks recommended for this investigation have a capacity of 30 ml. They arrive in a sterile condition and have a screw cap which permits tight sealing of the flask after it is filled. The shape of the flask permits its use on the stage of a compound microscope. Discourage the use of the high power objective, unless you have students who possess good microscope technique, and have the patience to examine the contents of the flask in great detail.

Remind the students that the scanning objective (3.5x-5x) will permit examining the entire depth of the flask, while the low power objective (10x) will permit examining only a portion of the depth of the flask. Therefore, the student will have to turn the flask over to examine the other side when using the low power objective. Since the flasks are stored on their side, many organisms will settle or adhere to one side of the flask. Do not shake the flasks or these organisms may be dislodged.

One gallon of media will be more than enough to fill 75 flasks, sufficient for 5 classes of 15 flasks each. If you do not have enough flasks, one set of flasks can be prepared for all the classes to observe.

If you collect water from a pond, obtain some bottom mud and filamentous forms of algae. Large, rooted plants and larger animals should be avoided. When filling the flasks, do not put too much solid material into them. Place only a small amount of detritus and plants in each flask.

If you collect water from a pond during the warm months of the year, it can be stored in an aquarium placed by a window and allowed to age. You only need to add water to reestablish the water level. From time to time, add fresh pond water to maintain the diversity of the culture.

An excellent source of certain types of microorganisms may be found in the filters of tropical fish aquaria. Shake one of these filters in a liter of water.

To prepare the flasks, shake or stir the medium, pour some of the material into the flasks until they are entirely full, and screw on the cover tightly to exclude any air.

If you can obtain a variety of media, mix them together to create a melange of communities. However, the introduction of the media into the flasks in itself causes a change in conditions from the original media. An ecological succession can be expected to occur.

The succession will be comparatively obvious, until a climax is established within the community in the flask. The changes in the populations, representing successional changes, can be determined by the student recording the relative frequencies of the organisms found. The student should be instructed to observe the morphology of the organisms only. There is no need to know the names of any of the organisms. Sketches will suffice. A suggested form for recording the data is shown in Possible Answers.

Discussion and Review: The data will show that different organisms undergo various increases, decreases, or assume a constant frequency within the population. Help the students to see that this flux is caused by the interaction of organisms competing for energy and space. The students should also see that the only energy input is in the form of light.

The discussion of the data should be concerned with the morphology of the organisms observed and not with any specific taxonomic knowledge. The purpose of this investigation is to observe succession. By the time the student finishes this investigation, he will have used his own ingenuity in developing a perception of shapes and forms which are useful for the morphological description of organisms.

Discuss the concept of a climax forest as illustrated in part D to help the student understand the concept of succession and climax.

Discuss the three basic ecological concepts covered in this investigation:

a. The idea of a closed community system in which there is only an energy input, and what happens to that system.

b. The concept of succession, the regular change in the numbers and types of organisms found in a community.

c. The idea of a climax, the development of a stable, self-perpetuating system within a community.

ENRICHMENT

1. Make a comparative study of the succession of culture media collected from different environments.

2. Make a comparative study of the succession of the same culture media kept under different environmental conditions.

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The Coniferous Forest Biome: 16 mm, color, 16 min., Encyclopaedia Britannica 2610.

Distribution of Plants and Animals: 16 mm, color, 16 min., Encylopaedia Britannica 2085.

The Forest Grows: 16 mm, color, 10 min., Encyclopaedia Britannica 432.

Life Along the Water Ways: 16 mm, color, 11 min., Encyclopaedia Britannica 560.

The Marsh Community: 16 mm, color, 11 min., Encyclopaedia Britannica 2396.

Microcosm in a Bromeliad: 8 mm film loop, color, Encyclopaedia Britannica 81335.

Plant-Animal Communities: Ecological Succession: 16 mm, color, 13.5 min., Coronet 1457.

Search at Shering: 16 mm, color, 25 min., Association Films S139.

Seashore Life: 16 mm, color, 11 min., Encyclopaedia Britannica 506.

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POSSIBLE ANSWERS

1. The population will reach a leveling or balance point and then the mouse population will decrease.
2. The mouse population would decrease. The number of cats would increase.
3. The *Penicillium* would increase and the bacteria would decrease.

TABLE NO. 1

OBSERVATION OF ORGANISMS IN A CLOSED SYSTEM OVER A SIX-WEEK PERIOD

Date	Organism	Frequency

The particular organisms which the students observe and which reach successional climax will vary, depending on the source of the water and a number of physical and biological factors.

4. No, the kinds of organisms changed from time to time.
5. No, different organisms were more plentiful at different times.
6. (Depends on data.)
7. (Depends on data.)
8. (Depends on data; hopefully different from answer given in "6" and "7.")
9. The changes took place more frequently during the early weeks of the six-week observation.
10. No, the same organisms were observed. They represented the strongest or the survivors.
11. The sun and from other organisms in the flask.
12. Competition for food, energy, and space. Finally, a dominant form of life prevailed.
13. A community.
14. Energy.
15. It will change as the various organisms compete for energy.
16. It will stabilize into a dominant or climax community.

CONCEPT SUMMARY: A community will change until a climax is established.

Collect a variety of waters beforehand for the students to test.

If you have the glassware, this experiment works better with 125 or 250 ml beakers or flasks instead of test tubes. See Practical Hints.

PURPOSE: Develop the concept that harmful factors can upset a mutually dependent community.

DEVELOPMENT: The students will test various water samples for the absence of oxygen, as an indicator of pollution. By reading about various environments, they will realize that a balanced community can be ruined by pollution.

HIGHLIGHTS: Unknown samples of water are tested by the students for the presence of oxygen and then students are asked to make a prediction about the quality of each of the waters for maintaining life. Their predictions are compared with the source of the waters which is subsequently revealed by the teacher.

MATERIALS (for each team of two)

- Test tubes, three
- Graduated cylinder, 10 ml
- Methylene blue, 5 ml[1]
- Test solution, 25-35 ml[2]
- Straw or length of rubber tubing, 8"
- Burner, Bunsen or alcohol
- Clamp, test tube
- Water from various sources[3]

Preparation of Materials

1. Mix 0.25 g methylene blue in 100 ml water.

2. The test solution is a buffer made by heating 8 g potassium hydroxide in 300 ml H_2O. Cool and stir in 10 g dextrose (glucose).

3. The students should be given at least three different samples of water, one fully aerated, one moderately aerated, and one poorly aerated.

Suggested sources of water include:

Fully aerated: tropical fish aquarium
tap or spring water; aerate or stir vigorously before using
unpolluted lake, pond, or stream water

Moderately aerated: gold fish aquarium without artificial aeration
nonaerated aquarium used to store growth of algae and microorganisms
sluggish or still lake, pond, or stream water

Poorly aerated: water containing a day's growth of yeast or bacteria
polluted stream, lake, or pond water

TEACHING TIPS

Responses to Expect: The students will immediately ask you to identify the source of each of the waters. It would be preferable to label each sample with a number. Treat each sample as an unknown from which the student must make predictions after considering the data. Do not reveal the sources of the waters until the very end of part A.

You can expect a very positive response from the students on the subject of pollution. Students are quick to perceive that pollution is endangering every element of our environment, and that ways must be found to make the earth, the water, and the air and space we live in our friends, rather than the enemies of life.

Practical Hints: If you have enough 125 or 250 ml beakers or flasks, use these instead of test tubes. The larger containers make it easier to aerate the water when it is poured back and forth between two containers. You will have to modify the instructions so that the student mixes an equal part of the sample with the test solution. In a 250 ml beaker, an ideal mixture is 75 ml sample and 75 ml test solution (buffer). Add 3 drops methylene blue.

Many water companies aerate their water by spraying it into the air to remove the flat taste. Obtain literature from your local water company to illustrate this concept.

In the presence of oxygen, methylene blue is blue in color. When oxygen is removed, the methylene blue is bleached and becomes colorless.

Discussion and Review: Begin this investigation by reviewing all of the past concepts. Use the concepts printed in the introduction to assist you. The three illustrations of a climax community review the last concept learned and provide the transition to this investigation. The question that follows the three illustrations, "Does a climax community ever change?" is the transition statement that leads into this investigation.

When discussing the pollution of Lake Erie, or any body of water, be sure to point out that pollution does not necessarily poison the life in the water. In fact, the pollutants may serve as a source of food for certain types of life, such as algae. The ecological succession then leads to a population explosion of bacteria. The oxygen depletion is caused by the excess algae and bacteria, not the pollutants. In time, the decay of the excess algae together with the additional pollutants cause what is commonly called pollution. Although pollution is the cry word of the day, do not let this overshadow the concept for this investigation, that external factors, such as pollution, can upset a mutually dependent community.

The "Hudson River Song" is a very easy song to sing and if you have a folk singer or guitarist in class, the song will have a greater impact if it is sung by the entire class. The melody can be found in *BITS AND PIECES, songs by Pete Seeger,* Ludlow Music, Inc. and Sanga Music, Inc.

This investigation, this Idea, and even the IIS program should conclude by applying the concept of mutual dependence to the relationship between man and his environment.

ENRICHMENT

1. Trace the pollution of Lake Erie, a well documented story that can be found easily by a student in the library.

2. Use the Winkler method to quantitatively measure the amount of dissolved oxygen in various samples of water. See the Evans article below for directions.

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Conserving Our Natural Resources: Filmstrip series, color, 7 filmstrips, 45 frames each, Encyclopaedia Britannica 9090.

Environmental Pollution: Filmstrip series, Ward's 70 W 3800.

The Everglades: Conserving a Balanced Community: 16 mm, color, 11 min., Encyclopaedia Britannica 2739.

The First Mile Up: 16 mm, black and white, 28 min., McGraw-Hill 672320.

The House of Man–Our Changing Environment: 16 mm, color, 17 min., Encyclopaedia Britannica 2206.

It's Your Decision, Clean Water: 16 mm, color, 14 min., Association Films 5823.

Man's Problem: 16 mm, color, 20 min., Encyclopaedia Britannica 713.

Modern Biology: Environment and Survival: Sound filmstrip series, color, 8 filmstrips, 485 frames, SVE 469-SR.

Our Endangered Wildlife: 16 mm, color, 51 min., McGraw-Hill 672336.

Our Vanishing Lands: 16 mm, color, 24 min., McGraw-Hill 672407.

Oxygen Levels During an Algal Bloom: 8 mm film loop, color, Ealing 81-6538/1.

Population and Food: Filmstrip, color, 40 frames, Popular Science 1521.

Population Ecology: 16 mm, color, 19 min., Encyclopaedia Britannica 2144.

Problems of Conservation–Air: 16 mm, color, 15 min., Encyclopaedia Britannica 2747.

Problems of Conservation–Forest and Range: 16 mm, color, 14 min., Encyclopaedia Britannica 2786.

The Problem with Water Is People: 16 mm, color, 30 min., McGraw-Hill 672046.

Science and Natural Resources: Filmstrip series, color, 3 filmstrips, 34 frames each, Encyclopaedia Britannica 9170.

Using Natural Resources: Filmstrip series, color, 3 filmstrips, 34 frames each, Encyclopaedia Britannica 9160.

POSSIBLE ANSWERS

1. It turned colorless.
2. Carbon dioxide.
3. Turned blue.
4. Colorless.
5. Oxygen.
6. Turned blue.

TABLE NO. 1

PRESENCE OF OXYGEN IN VARIOUS SAMPLES OF WATER

Sample	Color Reaction	Condition of Water	Source of Water
1	Blue	Not polluted	Tap water
2	Slightly blue	Slightly polluted	Unaerated classroom aquarium
3	Clear or colorless	Polluted	Yeast culture, day old

7. Oxygen.
8. Kills them or reduces their number.

9. Oxygen.
10. The fish will die first because they have a more critical need for oxygen.
11. The oxygen depletion (pollution) is caused by the population explosion of bacteria and algae.

CONCEPT SUMMARY: Destructive influences can upset a climax community.

IDEA SUMMARY: All living things constantly need energy as they interact with their environment.

LABORATORY APPARATUS AND SUPPLIES FOR IIS BIOLOGY

The pages which follow give a comprehensive listing of needed materials for the IIS Biology program. The materials are divided into four groups. The first, **Living Materials**, consists of items available from biological supply houses or locally. The second group, **Chemicals and Foods**, includes consumable materials, which can be obtained from your regular supplier or locally. The **Equipment** list includes hardware, glass, and plasticware, and other nonconsumable items. Many of the materials listed under **Miscellaneous Supplies** are consumable, although other items may be reused from year to year.

Quantities are listed per teacher or per class of 30. Quantities per class of 30 should be multiplied by the number of sections of IIS Biology to determine the total quantity needed in a particular school. A column headed "Quantity to Order" has been left blank for the teacher's convenience in preparing to order. A column headed "Source" has been filled in only for those items which *are* included in the IIS Biology equipment package prepared by Hickok Teaching Systems, Inc. This equipment package should be ordered through Prentice-Hall, Inc.

The last column of each page, headed "Used in Biology," gives each investigation in which the item is used. For example, for an item used in Idea 3, Investigation 4, the entry would read "3:4."

Frequently, suggestions for substitutions for specific items are given in the guides to individual investigations. Checking the individual guides before ordering may indicate substitute items already in your stockroom.

LIVING MATERIALS

Item	*Quantity per Teacher or per Class of 30*	*Quantity to Order*	*Source*	*Used in Biology*
Amoeba culture	1/teacher			3:3
B. subtilus or *B. cereus*	1 culture/teacher			5:8
Bean plants	3/class			5:2
Cockerels, day old	30/teacher			4:8
Daphnia	45/class			4:2
Elodea	2 bunches/class			2:5; 5:4
Flowers	15/class			3:4
Garden litter	1 lb/class			2:2
Garden soil	2 lb/class			2:2; 5:8
Goldfish	30/teacher			4:2
Hay	handful/class			2:2
Hydra culture	1/teacher			3:3
Leaves, green	100/class			5:2; 5:3
Leaves, on branch	15 branches/class			2:10
Mealworms	30/teacher			1:2; 1:9
Mouse (optional)	1/teacher			1:5
Paramecium culture	1/teacher			3:3
Seeds				
Bean, brown	9 lbs/teacher		P-H	3:4; 3:5
Bean, Kentucky Wonder	50/teacher		P-H	3:4; 5:2
Bean, white	3 lbs/teacher		P-H	3:4; 3:5
Oat	75/class		P-H	4:8
Okra	75/class		P-H	1:8
Pea, Alaska Round	3 lbs/teacher		P-H	1:3; 2:10; 3:4; 3:6; 3:11; 4:1; 4:8; 5:2
Pea, round yellow	1 lb/teacher		P-H	3:4
Pea, wrinkled	1 lb/teacher		P-H	3:4; 3:6; 3:11
Radish	75/class		P-H	1:8
Tobacco, genetic	2000/class		P-H	3:7
Snails	15/teacher			4:1
Water				
Aerated	500 ml/teacher			5:10
Pond	2 liters/teacher			2:4; 5:9; 5:10
Stagnant	500 ml/teacher			2:2; 5:10
Yeast, dry	4 pkg/teacher			2:5; 3:3; 4:7; 5:5

CHEMICALS AND FOODS

Item	*Quantity per Teacher or per Class of 30*	*Quantity to Order*	*Source*	*Used in Biology*
Acetone	100 ml/class			5:3
Acetylcholine	1 ml/teacher			4:2
Adrenalin	1 ml/teacher			4:2
Agar				
Nutrient	4 oz/teacher			2:2; 3:4; 3:7; 3:11; 5:8
Potato Dextrose	4 oz/teacher			2:2
Alcohol, ethyl or methyl	2 quarts/class			2:2; 5:2
Antibiotic discs	45/class			5:8
Benedict's solution	1 liter/class			4:6
Bouillon, beef	1 pint/class			3:1; 3:2
Calcium oxide	1 lb/teacher			1:4; 5:5
Coffee	5 ml/class			4:2
Congo red	1 g/teacher			4:7
Crackers, saltine	60/class			1:2; 4:6
Egg membranes	30 pieces/class			4:7
Fertilizer, liquid	1 pt/teacher			2:2
Foods, assorted	optional			1:9; 5:1
Glucose	10 g/class			5:10
Glucose-l-phosphate (optional)	1.5 g/class			3:11
Hydrochloric acid, conc.	1 ml/class			4:4
Ice	7 lb/class			4:3; 4:6
Indoleacetic acid	1 g/teacher			4:8
Iodine in ethanol	100 ml/class			4:3
Lemon juice	5 ml/class			1:1
Lugol's solution	25 ml/class			1:9; 3:11; 4:6; 5:2
Methyl cellulose (optional)	50 ml/teacher			2:4
Methylene blue	1 g/class			2:4; 2:5; 5:10
Molasses	50 ml/class			4:7
Nicotine solution	100 ml/teacher			4:2
Peanuts	15/class			5:1
Petroleum ether	100 ml/class			5:3
Phenol red	1 g/teacher			4:4
Potassium hydroxide	¼ lb/class			5:2; 5:6; 5:10
PTC paper	1 pkg/teacher		P-H	3:10
Rose bengal	1 g/teacher			2:2
Sodium bicarbonate	¼ lb/class			1:1; 1:4; 5:4
Sodium chloride	1 lb/teacher			1:2; 2:5
Sodium hydroxide	2 g/teacher			4:4
Starch, corn	2 g/class			4:6
Streptomycin	2 ml/teacher			2:2
Sugar				
Brown	450 g/class			2:5; 3:3; 4:7; 5:5
Sucrose	15 g/class			3:4; 4:7
Syrup, corn or maple	50 ml/class			4:7
Tea bags	4/class			1:1; 4:2
Testosterone ointment	10 ml/class		P-H	4:8
Tranquilizer	1 tablet/teacher			4:2
Vinegar	250 ml/class			1:2; 1:4

EQUIPMENT

Item	*Quantity per Teacher or per Class of 30*	*Quantity to Order*	*Source*	*Used in Biology*
Balance	15/teacher			1:5; 1:8; 2:2; 3:1; 3:2; 3:4; 3:7; 5:8
Bath scale, metric	1/teacher			1:5
Beaker, 250 ml	30/teacher			1:1; 4:6; 4:7; 5:2
Burner, alcohol or Bunsen	15/teacher			3:1; 3:4; 3:7; 4:6; 4:7; 5:2; 5:10
Clamp				
Pinch	15/class			2:2; 5:4; 5:6
Ringstand	15/teacher			5:1
Cockroach Race Track (optional)	15/teacher			1:9
Cover slip	30/class			2:2; 2:3; 2:4; 2:5; 3:3; 4:2; 4:7; 5:2; 5:7
Dropper bottle	15/teacher			1:1; 2:4; 2:5; 3:11; 4:2; 4:6; 4:7
Dropper				
Elongated tip	30/teacher		P-H	4:7; 5:4; 5:6
Medicine	30/teacher			2:2; 2:3; 4:2
File, triangular	1/teacher			3:1
Flashlight	15/teacher		P-H	1:6; 4:1
Flask				
Erlenmeyer, 125 ml	30/teacher			1:4; 1:5; 4:4
Tissue culture	15/class		P-H	5:9
Forceps	15/teacher			5:2; 5:6; 5:8
Funnel, aluminum, 4" top diameter	15/class			2:2
Graduated cylinder				
10 ml	15/teacher			4:6; 5:8; 5:10
100 ml	15/teacher			1:5; 2:2; 3:1; 3:2; 3:4; 3:7; 4:4; 4:8; 5:1
Jar				
1 pint	30/teacher			1:4; 1:5; 1:8; 2:2; 2:3; 2:11
1 quart, small mouth	15/teacher			1:5
Lamp, gooseneck	3/teacher			2:2; 4:3; 5:4
Lens, hand	15/teacher			2:2; 3:4; 5:7
Meter stick	15/teacher			1:1; 1:6; 1:7; 5:7
Microbiome (optional)	15/teacher			1:9
Microscope	15/teacher			2:2; 2:3; 2:4; 2:5; 3:3; 3:12; 4:2; 4:7; 5:2; 5:7; 5:9
Microscope slides	15/class			2:2; 2:3; 2:4; 2:5; 3:3; 3:11; 4:2; 4:7; 5:2; 5:7

Equipment (continued)

Item	*Quantity per Teacher or per Class of 30*	*Quantity to Order*	*Source*	*Used in Biology*
Mortar and pestle	15/teacher			3:11; 5:3
Pan or pail, large	15/teacher			1:5; 4:3
Petri dish, plastic	60/class			1:2; 1:3; 2:2; 2:10; 3:4; 3:6; 3:7; 3:11; 4:1; 4:2; 4:8; 5:2; 5:8
Pressure cooker or sterilizer	1/teacher			3:1
Refrigerator (optional)	1/teacher			3:11
Ring	15/teacher			5:2; 5:3
Ringstand	15/teacher			5:1; 5:2; 5:3
Rod				
L-shaped, glass	15/teacher		P-H	5:8
Stirring, glass	15/teacher			1:1; 4:3; 4:4; 5:1
Saucepan	1/teacher			3:1; 3:2; 3:4; 3:7
Scissors	15/teacher			1:2; 2:3; 3:7; 3:12; 4:1; 4:8; 5:2
Spoon, chemical	15/teacher			2:2
Stakes	60/class			5:7
Stopper				
Cork	15/teacher			5:1; 5:3
Rubber, 1-hole	15/teacher			1:4; 5:5
Rubber, 2-hole	30/teacher			1:4; 5:4; 5:6
Test tube holder, wire	15/teacher			4:6; 5:10
Test tube rack, 5-hole	15/teacher			1:4; 3:1
Thermistor-thermometer (opt)	1/teacher			4:3
Thermometer				
Laboratory	8/teacher			4:3; 5:1
Oral	8/teacher			4:3
Tube				
Culture or test	90/class			1:3; 1:4; 1:9; 3:1; 3:2; 4:6; 4:7; 5:1; 5:2; 5:3; 5:4; 5:5; 5:6; 5:8; 5:10
Y-shaped	15/teacher		P-H	1:4
Tubing, glass				
2" x 6", 90° bend	15/teacher		P-H	1:4
4", straight	30/teacher		P-H	1:4; 3:1; 5:4; 5:5; 5:6
6", straight	30/teacher		P-H	1:4
8-10", capillary	15/teacher		P-H	5:4; 5:6
S bend	15/teacher		P-H	3:1
Tubing, rubber				
¼" o.d., 10"	30/class			1:4; 5:4; 5:5; 5:6; 5:10
½" o.d.	4 ft/class			2:2

MISCELLANEOUS SUPPLIES

Item	*Quantity per Teacher or per Class of 30*	*Quantity to Order*	*Source*	*Used in Biology*
Aluminum foil	1 roll/class			2:8; 3:1; 4:1
Can, juice				
6 oz	15/teacher			5:1
46 oz	2/class			4:1
Candle, birthday	15/class			5:1
Cardboard, 8½" x 11"	15/teacher			3:4
Cheesecloth	2 sq yd/class			2:2
Chick brooder	1/teacher			4:8
Chick mash	10 lbs/teacher			4:8
Classification game	8/teacher		P-H (opt)	2:6; 2:7
Cotton, sterile	1 roll/teacher			3:1; 4:2; 4:3; 5:6; 5:8
Data punch cards	225/class		P-H	2:7
Envelopes, Kraft	90/teacher			3:6
Felt pen	15/teacher			4:1
Film loop				
Amoeba reproduction (opt)	1/teacher			3:3
Paramecium reproduction (opt)	1/teacher			3:3
Filter paper strips	45/class		P-H	5:3; 5:8
Fossil kit	1/teacher		P-H	2:8
Glue	15 bottles/teacher			3:12
Golf ball, plastic	15/teacher			1:3
Homeostasis game	8/teacher		P-H (opt)	4:10
Hook				
Cup, 3/4"	90/teacher		P-H	1:7
Screw, angle	15/teacher		P-H	1:7
IIS Color Kit	15/teacher		P-H	2:11
IIS Shape Kit	15/teacher		P-H	2:6
IIS Size Kit	15/teacher		P-H	2:11
Index cards	60/class			1:1; 1:5; 4:7
Ink	1 bottle/teacher			5:4
Magazines	9/teacher			1:2
Marbles	15/teacher			1:3
Matches	1 box/teacher			5:1
Mirror, pocket size	15/teacher		P-H	1:7
Newspaper, classified	1 piece/class			2:3
Overlay, printed	15/teacher		P-H	4:1
Paper				
Bags	45/teacher			3:5; 3:8
Binder	15 sheets/class			1:5
Bond	15 sheets/class			4:3
Lens	1 pkg/class			2:3; 2:4; 2:5
Towels	400/class			1:2; 1:3; 1:8; 2:3; 2:4; 3:7; 3:11; 4:1; 4:3; 4:8
Weighing (waxed)	1 roll/teacher			2:2
Paper clip	30/teacher			1:5; 2:7; 5:3
Paraffin	1 lb/class			2:8
Pencil	15/teacher			1:3; 2:8
Pin, straight	15/class			5:1

Miscellaneous Supplies (continued)

Item	*Quantity per Teacher or per Class of 30*	*Quantity to Order*	*Source*	*Used in Biology*
Plastic bags	15/class			3:7
Plastic chips				
Brown	60/teacher		P-H	3:8; 3:9; 3:10
Clear	60/teacher		P-H	3:8; 3:9; 3:10
Plastic, polyethylene, 8" x 8", 1-4 mil thick	30/class			1:3
Plastic, Saran	1 roll/class			1:3; 3:4; 5:2
Play-Doh, 4" x 2" x ½"	15 pieces/class			2:8; 5:1
Playing cards (optional)	1 deck/teacher			2:6
Preserved specimens	optional			2:1
Prepared slides				
Assorted	optional			2:5
Onion root tip mitosis	15/teacher			3:3; 3:12
Probability device	15/teacher		P-H	1:7; 2:10
Razor blade	15/teacher			3:4
Rubber bands	30/class			1:3
Ruler				
Metric, transparent	15/teacher			2:3
12" and 30 cm	15/teacher			1:2; 1:6; 1:7; 1:8; 2:10; 4:8; 5:4; 5:6; 5:7
Sand, coarse	1 cup/teacher			2:3; 5:3
Scoop, 25 ml	15/teacher		P-H	3:5
Shoebox	15/teacher			1:3; 2:11; 4:1; 4:8
Soap solution	100 ml/class			2:8
Straws, clear plastic	100/class			1:4; 1:5; 4:4; 4:7
String	1 roll/class			1:3; 2:2; 3:1; 5:7
Tape				
Cellophane	1 roll/teacher			4:7
Masking	1 roll/class			1:5; 2:2; 3:11; 4:1; 4:6
Metric	15 ft/class		P-H	1:5
Thread	1 spool/teacher			4:7
Toothpicks	1 box/teacher			2:5; 5:3
Wire screen, 6" diameter	15/class			2:2
Wood block, 1½" cube	90/teacher		P-H	1:3; 1:5; 1:7
Wood strip, 3/8" x 3/4" x 10"	15/class		P-H	1:5

SUPPLIERS OF LABORATORY APPARATUS

Prentice-Hall, Inc.
Educational Book Division
P.O. Box 900
Englewood Cliffs, N.J. 07632

CalBioChem
3625 Medford Street
Los Angeles, California 90063

Carolina Biological Supply Company
2700 York Road
Burlington, North Carolina 27215

Carolina Biological Supply Company
Powell Laboratories Division
Gladstone, Oregon 97027

Falcon Plastics
1950 Williams Drive
Oxnard, California 93030

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Framingham, Massachusetts 01701

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Chicago, Illinois 60620

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757 Third Avenue
New York, New York 10017

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Scientific Manufacturing Industries
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Yellow Springs, Ohio 45378

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Cambridge, Massachusetts 02140

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425 North Michigan Avenue
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146-01 Archer Avenue
Jamaica, New York 11435

Folkways/Scholastic
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Society for Visual Education, Inc.
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Chicago, Illinois 60614

Thorne Films
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Boulder, Colorado 80302

Ward's Natural Science Establishment, Inc.
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Rochester, New York 14603

Warren Schloat Productions, Inc.
Pleasantville, New York 10570

Webster Division
McGraw-Hill Book Company
Manchester Road
St. Louis, Missouri 63011

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